EL-MOASSER

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Interactive E-learning Application

CHEMISTRY

MAIN BOOK

2nd SEC. 2023

FIRST TERM

Chapter 1 Atomic Structure

Lesson One
From: Introduction of atomic structure.
Until: Before atomic emission spectra.

Lesson Two
From: Atomic emission spectra.
Until: Before the quantum numbers.

Lesson Three
From: The quantum numbers.
Until: Before principles of distributing electrons.

Lesson Four
From: Principles of distributing electrons.
Until: The end of the chapter.

Exam model on the chapter

Chapter 2 The Periodic Table and Classification of Elements

Lesson One
From: The long form (modern) periodic table.
Until: Before trends and periodicity of properties in the periodic table.

Lesson Two
From: Trends and periodicity of properties in the periodic table.
Until: Before metallic and nonmetallic property.

Lesson Three
From: Metallic and nonmetallic property.
Until: Before the oxidation numbers.

Lesson Four
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Until: The end of the chapter.

Exam model on the chapter

18 Open Book exam models, including :

- Exam of the ministry of Education 2021
- Questions of the exam of 2020
- Guiding model of the Ministry of Education.
- 15 exam models on the first term curriculum.

CHAPTER

1

Atomic Structure

Lesson One

From: **Introduction of atomic structure.**

Until: **Before atomic emission spectra.**

Lesson Two

From: **Atomic emission spectra.**

Until: **Before the quantum numbers.**

Lesson Three

From: **The quantum numbers.**

Until: **Before principles of distributing electrons.**

Lesson Four

From: **Principles of distributing electrons.**

Until: **The end of the chapter.**

Exam model on the chapter

Learning outcomes

By the end of this chapter, the student will be able to :

- Recognize the historical background of atomic structure.
- Describe the properties of cathode rays.
- Discuss Rutherford's atomic model.
- Recognize Bohr's atomic model.
- Define the reasons of the inadequacy of Bohr's model.
- Construes the modification introduced by the modern atomic theory.
- Explain the concepts of electron cloud and orbital.
- Define the four quantum numbers.
- Distribute electrons of any atom considering the building-up principle. Hund's rule and Pauli's exclusion principle
- Appreciate the efforts of scientists in the development of chemistry.

Chapter 1

Lesson One

From Introduction of atomic structure

Until Before atomic emission spectra

Evolution of the concept of the atomic structure

Scientists were interested in studying the atomic structure

1 Heisenberg. 2 Pauli. 3 Schrödinger. 4 Bohr.

5 De Broglie. 6 Einstein. 7 Planck.

Long time ago man wondered about the nature of matter and its structure ?!

Through the trials done by the scientists to answer this question across different eras, the concept of the atomic structure is evolved (developed).

In the following, the historical evolution of atomic structure concept will be discussed:

1. Democritus's idea.
2. Aristotle's idea.
3. Boyle's idea.
4. Dalton's model of the atom.
5. Thomson's model of the atom.
6. Rutherford's model of the atom.
7. Bohr's model of the atom.
8. The modern atomic theory.

1 Democritus's (Greek philosopher) idea

Democritus

He imagined the possibility of dividing any piece of matter to smaller parts, then dividing those parts into smaller particles and so on, until an indivisible (indestructible) fragment is obtained, he named it an "atom".

Democritus's atomic concept

Note

atom in the Greek language is a word of two sections :
- a means no.
- tom means divide.

2 Aristotle's idea (4th Century B.C)

Aristotle

- He rejected the former concept of the atom and believed that matter - whatever its nature - is composed of four components, which are water, air, dust and fire.
- It was believed that cheap metals as iron or copper can be changed into precious ones as gold by changing the proportions of these four constituents.
- This illogical idea had blocked the development in chemistry science for more than thousand years, because the scientists were busy trying to change cheap metals into precious ones.

Aristotle's atomic concept

3 Boyle's idea (1661)

The Irish scientist Boyle rejected Aristotle's idea about the nature of matter and gave the first definition of the element.

Element is a pure simple substance that can't be changed to simpler forms by the traditional chemical methods.

Boyle

4 Dalton's model of the atom (1803)

The English scientist John Dalton stated the first theory about the atomic structure.

J. Dalton

The main postulates of Dalton's atomic theory

1. The element is composed of very minute particles, named atoms.
2. The atom is a very minute indivisible solid particle.
3. Masses of atoms of the same element are similar, but they differ from one element to another.
4. The compounds are formed by the combination of atoms of different elements in simple numerical ratios.

Dalton's atom (solid, indivisible)

* This last postulate is known as **the law of constant proportion** which states that each compound always contains the same elements in the same proportion (by mass) no matter how different the method of its preparation.

Worked Example

32 g of sulphur react completely with 48 g of oxygen to form 80 g of sulphur trioxide. What is the mass of sulphur trioxide which is produced from mixing 16 g of sulphur with excess amount of oxygen under suitable conditions for the reaction ?

(a) 24 g
(b) 40 g
(c) 56 g
(d) 80 g

Idea of answering :

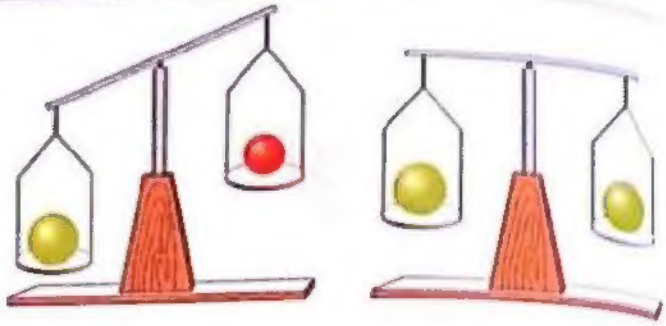
Sulphur	+ Oxygen	$\longrightarrow$ Sulphur trioxide
32 g	48 g	80 g
16 g		? g

The produced mass of sulphur trioxide $= \frac{80 \times 16}{32} = 40$ g

Answer : The correct choice is (b)

Test Yourself

The opposite figure represents one of the postulates of an atomic theory that you have studied, these balls represent the atoms of two different elements. Whose theory is this ?



(a) Dalton. (b) Democritus.

(c) Aristotle. (d) Boyle.

Idea of answering :

It is shown in the figure that the masses of the atoms of the same elements are .... , but they .... from one element to another.

This is exactly one of the postulates of ....'s theory.

Answer : The correct choice is ....

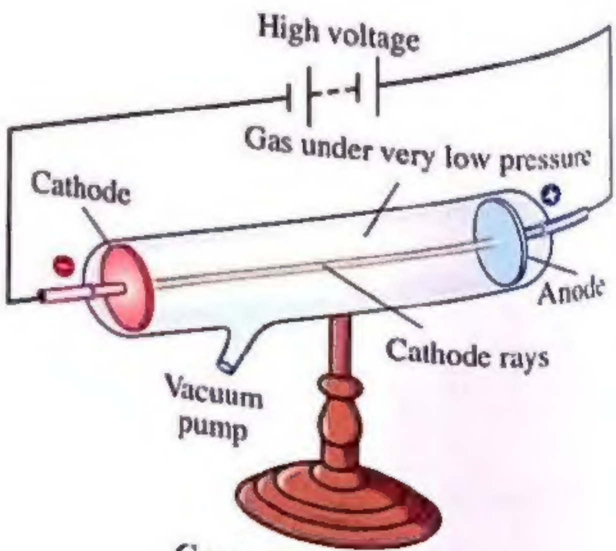
5 Thomson's model of the atom (1897)

The scientist Thomson carried out many experiments on the electric discharge through gases, from which he had discovered the cathode rays.

Thomson

Discovery of cathode rays (1897) :

- It was known that gases do not conduct electricity under normal conditions of pressure and temperature.
- However, gases conduct electricity in a discharge tube whose two electrodes are connected to an electric source with a suitable potential difference between its poles and under very low pressure.
- If the potential difference between the two poles of the discharge glass tube increases to around 10000 volts, a stream of invisible rays will be emitted from the cathode (the negative pole), causing a fluorescent glow on hitting the tube wall. These rays were named **"cathode rays"**.
- It was later known that these rays are composed of minute particles named **"electrons"**.

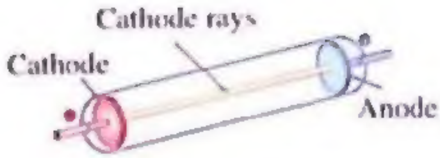


Generating cathode rays

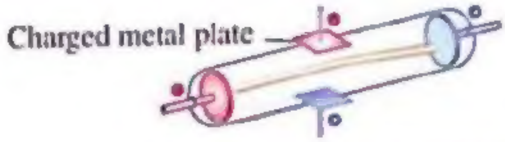
Properties of cathode rays :

1. They are formed of very fine negatively charged particles with negligible masses (electrons).
2. They move in straight lines (where their speed is lower than the speed of light).
3. They have a thermal effect.
4. They are affected by both electric and magnetic fields.
5. They do not vary with the nature of cathode material, or that of the used gas, this is a strong evidence that they are a fundamental constituent of any matter.

In the light of the electrical discharge experiment, Thomson suggested a new atomic model.



Move in straight lines

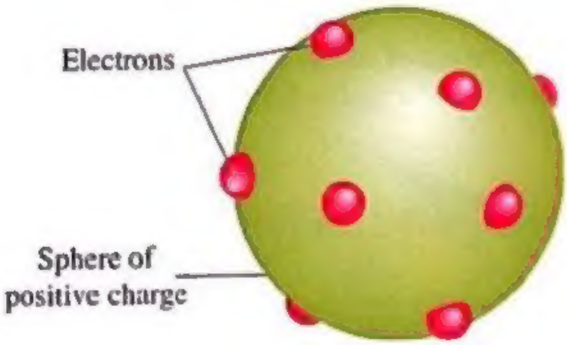


Negatively charged particles are affected by electric field

Affected by magnetic field

The postulate of Thomson's model

He considered the atom as a solid sphere of uniform positive electric charges in which a number of negatively charged electrons is embedded to make the atom electrically neutral.



Thomson's model of atom (solid)

Thomson's model of atom resembles a watermelon

Test Yourself

Dalton and Thomson agreed on that carbon atom ....

(a) has no spaces within it.

(b) is electrically neutral.

(c) contains negative electrons.

(d) is a homogenous sphere.

Answer : The correct choice is ....

6 Rutherford's model of the atom (1911)


Rutherford

Rutherford's students Geiger and Marsden had performed his famous laboratory experiment.

Rutherford's experiment

The used tools :

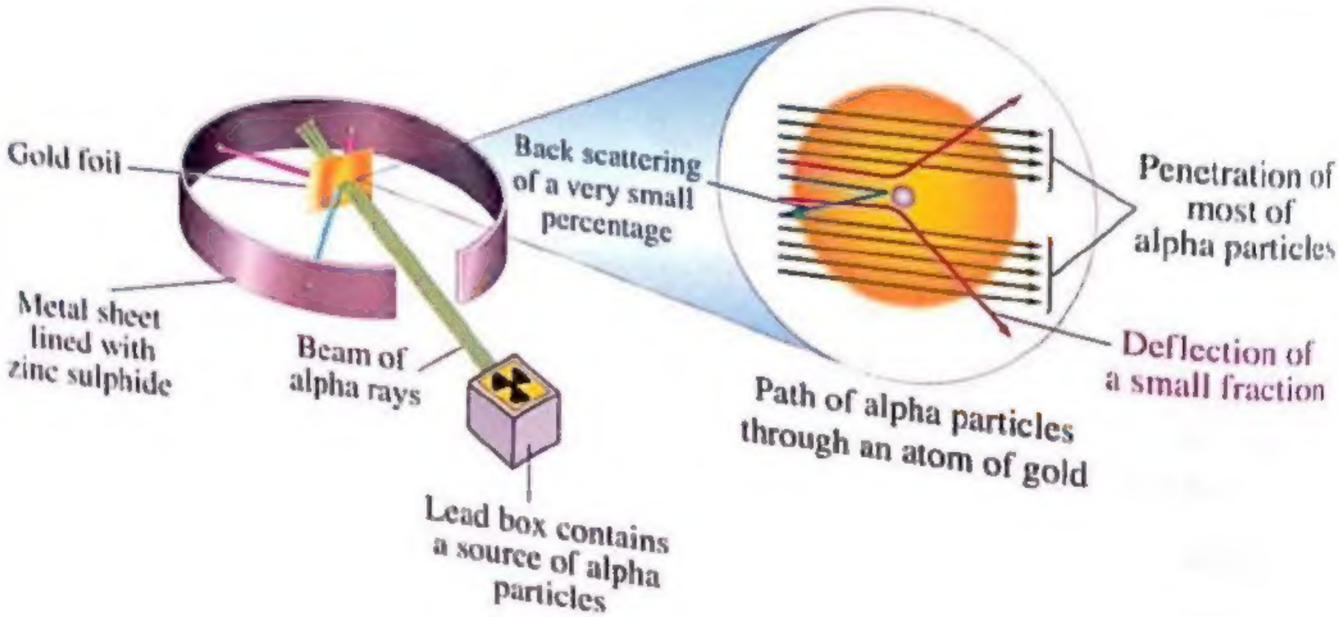
- A deep lead box containing a source of alpha particles inside it.
- A metal sheet lined with a layer of zinc sulphide ZnS
- A very thin gold foil.

Note

Zinc sulphide ZnS is used in detecting the invisible alpha particles, as they glow (flash) at the positions where they collide with this substance

The procedure :

1. The positive alpha particles (α) were allowed to collide with the metal sheet, where it was possible to define the location and the number of alpha particles by counting the flashes which appeared on the metal sheet.
2. A very thin gold foil was placed between the beam of alpha particles and the metal sheet.



Rutherford's experiment

• **Rutherford recorded his observations and reached the following conclusions :**

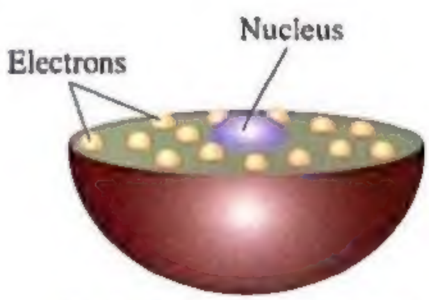
Observations :	Explanations :	Conclusions :
(1) The appearance of a large number of flashes at the same positions where they appeared before placing the gold foil.	* The penetration of the majority of α-particles through the gold foil without deflection.	* Most of the atomic volume is an empty space (**i.e.** the atom is not a solid ball as proposed by Dalton and Thomson).
(2) The appearance of some flashes on the other side of the metal foil (in front of the foil).	* A very small percentage of α-particles did not penetrate the gold foil and reflected (bounced) back.	* The atom contains a tiny part of a very high density, **and** most of the atomic mass is concentrated in this part (was named the nucleus).
(3) The appearance of some flashes on both sides of the position where they appeared before and after placing the gold foil.	* A small fraction of α-particles penetrated the foil but deflected from their path (where one α-particle of every 20000 emitted particles deflected from its path).	* The dense part of the atom (where most of the atomic mass is present) has a positive charge similar to that of α-particles, so they are repelled on approaching to this part (the nucleus).

Based on his experiment and other else, Rutherford designed the first atomic model on trial basis.

The postulates of Rutherford's atomic theory

1 Atom :

- It is an extremely small sized particle.
- It has a complicated structure which resembles the solar system, since it's composed of a central nucleus (representing the sun), and the electrons revolve around it (representing the planets).



Rutherford's atomic model

2 Nucleus :

- It is much smaller than the atom and most of the atomic mass is concentrated in it.
- There is a vast space between the nucleus and the orbits of electrons (i.e. the atom is not solid).
- It is positively charged.

3 Electrons :

- They have negligible mass compared to that of the nucleus.
- Their charge is negative and equals the nuclear positive charge (i.e. the atom is electrically neutral).
- They travel around the nucleus at a tremendous speed in special orbits, despite the mutual attraction between them and the nucleus. This attraction force is equal in quantity and opposite in direction to the centrifugal force resulting from their revolving around the nucleus, that is why the electron doesn't fall into the nucleus in spite of the attraction between them.

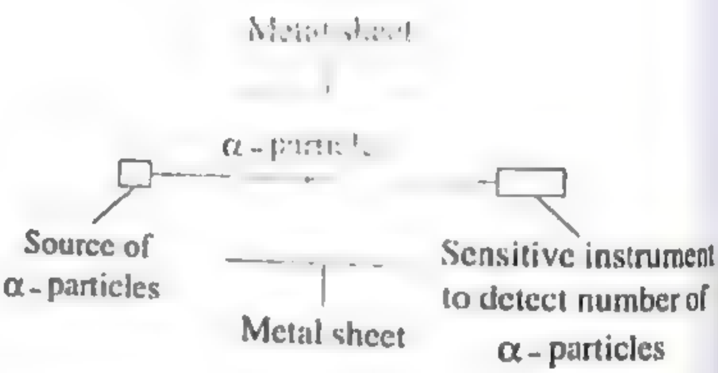
Drawback of Rutherford's atomic model

Rutherford's theory had failed to explain the atomic structure, because it didn't explain the system in which electrons revolve around the nucleus.

Worked Example

The opposite figure represents the path of a beam of α-particles between two metal sheets in vacuum conditions.

What happens to the reading of the sensitive instrument upon charging the two metal sheets with different charges ?



ⓐ It does not change.

ⓑ It increases.

ⓒ It decreases.

ⓓ It increases for a period of time, then it returns to the initial reading.

Idea of answering :

∵ Alpha particles are positively charged.

∴ Upon charging each metal sheet with a different charge, alpha particles repel the positively charged metal sheet drifting away from the sensitive instrument, consequently its reading decreases.

Answer : The correct choice is ⓒ

Included information

- The scientists verified the presence of the electrons, the protons and the neutrons in the atom throughout the 19^{th} and 20^{th} centuries.
- When a beam of each of these particles is passed through an electric field, **the following will happen :**
  - Neutrons :
    They are not deflected (continue in a straight line), as they are electrically neutral.
  - Protons :
    They are deflected towards the negative electrode, as they are positively charged.
  - Electrons :
    They are deflected towards the positive electrode, as they are negatively charged.
- Electrons are deflected **more strongly than** the protons, as the mass of the electrons is negligible compared to that of the protons.

Test Yourself

Which of the following are not deflected by the effect of the charged plates ?

(a) Cathode rays.

(b) Alpha particles.

(c) Protons.

(d) Hydrogen atoms.

Idea of answering :

∵ Cathode rays are .... charged.

∴ The choice (a) is excluded.

∵ Each of alpha particles and protons are .... charged.

∴ The choices (b) and (c) are excluded.

Answer : The correct choice is ....

Ready

Preliminary questions to remember the principal concepts in the lesson

Answer them yourself

Choose the correct answer for each of the following sentences :

(1) Who is the scientist who believed that matter is composed of water, dust, air and fire ?

a. Bohr. b. Rutherford. c. Dalton. d. Aristotle.

(2) What is the name of the scientist who was the first to define the atom ?

a. Dalton. b. Aristotle. c. Democritus. d. Thomson.

(3) The scientist who hypothesized that the compounds are composed of certain elements combined in a simple numerical ratio is ....

a. Dalton b. Schrödinger

c. Thomson d. Bohr

(4) Electric discharge experiment of Thomson proved that the atom ...

a. is solid.

b. contains a vast space.

c. contains a positively charged nucleus.

d. contains negatively charged electrons.

(5) Which of the following cases is a gas that conducts electricity ?

a. Hydrogen gas at normal conditions.

b. Neon gas upon its decomposition.

c. Argon gas under high pressure and low voltage.

d. Chlorine gas under low pressure and high voltage.

(6) The cathode rays consist of very fine particles called ....

a. electrons. b. protons.

c. α-particles. d. photons.

(7) Which of the following properties is the strong evidence which proved that the cathode rays exist in all materials ?

a. They have a thermal effect.

b. They move in straight lines.

c. They consist of very fine particles.

d. They are not different either in behavior or in nature, even if the material of the cathode is changed.

(8) Which of the following rays are deflected towards the positive pole when they are affected by the electric field ?

a. Alpha. b. Cathode. c. Gamma. d. X-rays.

(9) The scientist (1) stated the first atomic theory, while the scientist (2) designed the first atomic model on trial basis.

Which of the following identifies who the two scientists are ?

Choices	Scientist (1)	Scientist (2)
a.	Dalton	Thomson
b.	Dalton	Rutherford
c.	Rutherford	Dalton
d.	Rutherford	Thomson

(10) The metal sheet used in Rutherford's experiment is lined with a layer of ....

a. ZnS_2 b. $ZnSO_3$ c. Zn_2S d. ZnS

(11) In Rutherford's experiment, the deflection of a small fraction of α-particles shows that the atom contains ....

a. electrons. b. protons. c. nucleus. d. neutrons.

(12) Rutherford's theory proved for the first time that the atom ....

a. is indivisible. b. is electrically neutral.

c. contains a vast space. d. is solid.

(13) The scientist who discovered that the electrons have a negligible mass compared to that of the nucleus is ....

a. Thomson. b. Bohr. c. Rutherford. d. Dalton.

Steady

Open book questions

Answers

Multiple choice questions

Aristotle's idea

1 The scientist who refused the perception that matter is composed of atoms is ....

(a) Democritus.

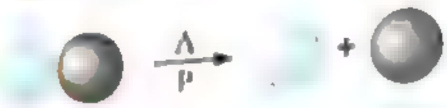
(b) Dalton.

(c) Aristotle.

(d) Bohr.

Boyle's idea

2 What is the choice which represents Boyle's idea about the element ?

(a) 

(b) 

(c) 

(d) 

Questions marked by this mark their ideas are explained in the answers

Dalton's model of the atom

3 Each of the following is among Dalton's theory postulates, except that ....

(a) atoms of the elements contain protons, neutrons and electrons.

(b) the masses of the atoms of the same element are similar.

(c) the atom is indivisible.

(d) each element is formed of tiny particles called atoms.

4 Which of the following examples agrees with Dalton's postulates ?

(a) The atoms which are found in a sample of chlorine resemble those which are found in a sample of sulphur.

(b) The properties of the molecules of hydrogen and oxygen differ from their properties in water molecules.

(c) Hydrogen can combine with oxygen to form water in more than one numerical ratio.

(d) Atoms which form magnesium element are tiny.

5 Which of the following facts does not match Dalton's atomic model ?

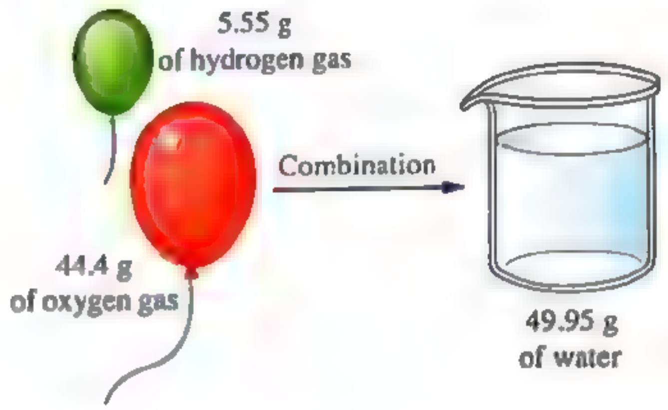
(a) The mass of each atom of copper atoms equals 63.5 u

(b) The mass of iron atom is less than that of copper atom.

(c) Uranium–285 nucleus undergoes fission forming lead.

(d) Hydrogen molecule is composed of two atoms.

6 The opposite figure represents one of the postulates of an atomic theory you have studied. Whose theory is this ?



(a) Thomson's.

(b) Bohr's.

(c) Dalton's.

(d) Rutherford's.

7 The ratio of the number of hydrogen atoms to that of nitrogen atoms in ammonia molecule is 3:1, this is consistent with one of the postulates of ....

(a) Thomson's theory. (b) Rutherford's theory.

(c) Bohr's theory. (d) Dalton's theory.

8 What is the mass ratio of carbon [C = 12] to hydrogen [H = 1] in methane CH_4 ?

(a) 1 : 4 (b) 3 : 2

(c) 3 : 1 (d) 4 : 1

9 48 g of oxygen react completely with 32 g of sulphur to form 80 g of sulphur trioxide. What is the mass which remains in the container after the end of the reaction, produced from adding 100 g of oxygen to 16 g of sulphur in suitable conditions for the reaction ?

(a) 40 g (b) 16 g

(c) 100 g (d) 116 g

10 Dalton concurred Democritus that ....

(a) the element has no atoms.

(b) the compound is formed by the combination of its elements in constant ratios.

(c) the atom contains a vast space.

(d) the atom is indivisible.

11 **Electrical neutrality was first mentioned in ....**

(a) Democritus's perception of matter.
(b) Dalton's atom.
(c) Boyle's concept of matter.
(d) Thomson's atom.

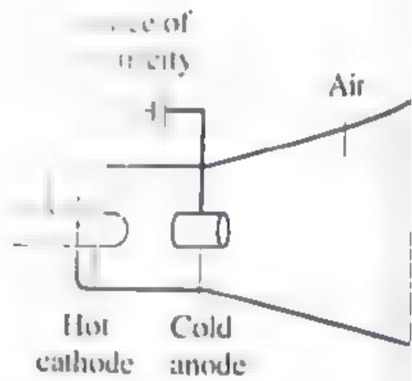
12 **When the potential difference between the two electrodes of a discharge tube reaches around 10000 volts, it is noticed that ....**

(a) the electrical conductivity of the gas in the tube decreases.
(b) the resistance of the gas in the tube to the electron passage increases.
(c) a flash occurs at the cathode on the wall of the discharge tube.
(d) a flash occurs at the anode on the wall of the discharge tube.

13 **Particle like character of cathode rays is indicated by ....**

(a) their ability to move in straight lines.
(b) their ability to induce flashes on the sensitive plates.
(c) their deviation when passed in an electric or a magnetic field.
(d) their thermal effect.

14 **The apparatus which is illustrated in the opposite figure does not produce cathode rays. What is the modification which should be introduced to obtain the rays ?**



(a) Altering the connection of the electrodes of the source of electricity.
(b) Heating the anode instead of the cathode.
(c) Using an alternating current source instead of direct current source.
(d) Discharging the air from the tube.

15 **Which of the following represents the electrical discharging experiment, and the properties of the produced cathode rays ?**

Choices	Source of the cathode rays	Effect of an electrical field on these rays
(a)	The positive cathode	The rays are deviated towards the positive electrode
(b)	The negative anode	The rays are deviated towards the negative electrode
(c)	The positive anode	The rays are deviated towards the negative electrode
(d)	The negative cathode	The rays are deviated towards the positive electrode

16 **All the following are among the properties of the cathode rays, except being ....**

ⓐ a stream of electrons.

ⓑ charged particles.

ⓒ moving at the speed of light.

ⓓ deflected by the effect of a magnetic field.

17 **Cathode rays have ....**

ⓐ mass only.

ⓑ charge only.

ⓒ neither mass nor charge.

ⓓ mass and charge.

Rutherford's model of the atom

18 **Rutherford's model of atom ....**

ⓐ is the recently accepted model of atom.

ⓑ assumed that the atom is solid.

ⓒ explained the unique atomic spectrum of the different elements.

ⓓ assumed that the charge of the electrons equals the charge of the nucleus.

19 **Which of the following postulates belongs to Rutherford's model but not Thomson's ?**

ⓐ The atom is a sphere of uniform positive electric charges.

ⓑ The atom contains negatively charged electrons.

ⓒ The atom contains a positively charged nucleus.

ⓓ The atom is electrically neutral.

20 **Which of the following observations shows the invalidity of the claim that the atom is solid, as presumed by Thomson and Dalton ?**

ⓐ Deviation of some alpha particles upon collision with the gold foil.

ⓑ Penetration of a small fraction of alpha particles upon collision with the gold foil.

ⓒ Reflection of a small percentage of alpha particles upon collision with the gold foil.

ⓓ Appearance of flashes on the sensitive plate behind the gold foil after falling of alpha particles on it.

21 **The gold foil experiment which was carried out in Rutherford's lab ....**

ⓐ confirmed Thomson's atomic theory.

ⓑ is the base for Dalton's theory.

ⓒ led to discovering the nucleus of the atom.

ⓓ included using of a source of beta particles.

22 After carrying out Rutherford's experiment using a foil of gold and alpha particles. All the following were concluded, **except** ....

ⓐ the small size of the nucleus of the atom.

ⓑ the charge of the nucleus.

ⓒ the atomic masses of the elements.

ⓓ the presence of the electrons around the nucleus.

23 When alpha particles and cathode rays are exposed to an electric field or a magnetic field, they ....

ⓐ move with the same speed.

ⓑ pass in opposite directions from each other.

ⓒ pass together in the same direction.

ⓓ are not affected by either of them.

24 Each of the following is passed in an electric field :

(1) Alpha rays. (2) Cathode rays.

(3) A group of the nuclei of the atoms of different elements.

Which of the following expresses the path of each of (1), (2) and (3) in this field ?

Choices	(1)	(2)	(3)
ⓐ	Deviated towards the positive pole	Take a straight path	Deviated towards the negative pole
ⓑ	Deviated towards the negative pole	Deviated towards the positive pole	Take a straight path
ⓒ	Deviated towards the negative pole	Deviated towards the positive pole	Deviated towards the negative pole
ⓓ	Deviated towards the positive pole	Deviated towards the positive pole	Deviated towards the negative pole

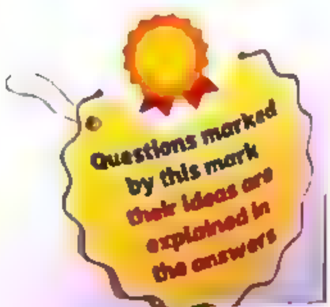
25 In Rutherford's experiment, the ratio of the number of the deviated alpha particles to that of alpha particles which bounced back is ....

ⓐ more than 1

ⓑ less than 1

ⓒ equal to 1

ⓓ infinite number.



26 **The failure of Rutherford's atomic model is attributed to that it did not explain ....**

ⓐ the nature of the movement of the electrons around the nucleus.

ⓑ the presence of a nucleus in the atom.

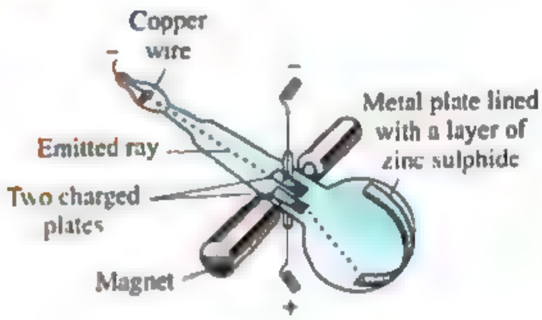
ⓒ the presence of attraction forces between the protons and the electrons.

ⓓ the presence of space between the nucleus and the electrons.

Essay questions

27 The illustrated experiment was carried out in a laboratory.

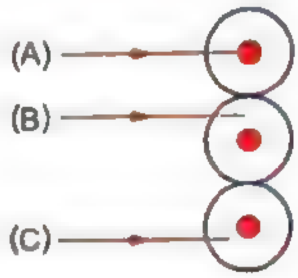
What is the effect of replacing the copper wire with an iron wire on the rays emitted from it ? Explain.



28 The opposite figure shows Rutherford's experiment.

Which of alpha particles (A , B or C) will flash at the same position before and after placing the gold foil ?

Explain your answer.



29 **The opposite figure illustrates falling of three α-particles on a gold foil :**

- **Particle (A) :** Moves towards the nucleus of the atom of gold.
- **Particle (B) :** Moves close to the nucleus of the atom of gold.
- **Particle (C) :** Moves in the space surrounding the nucleus of the atom of gold.

(1) Complete the path of the three particles on the figure.

(2) Show the importance of using a huge number of α-particles in this experiment.

Chapter 1

Lesson Two

From Atomic emission spectra

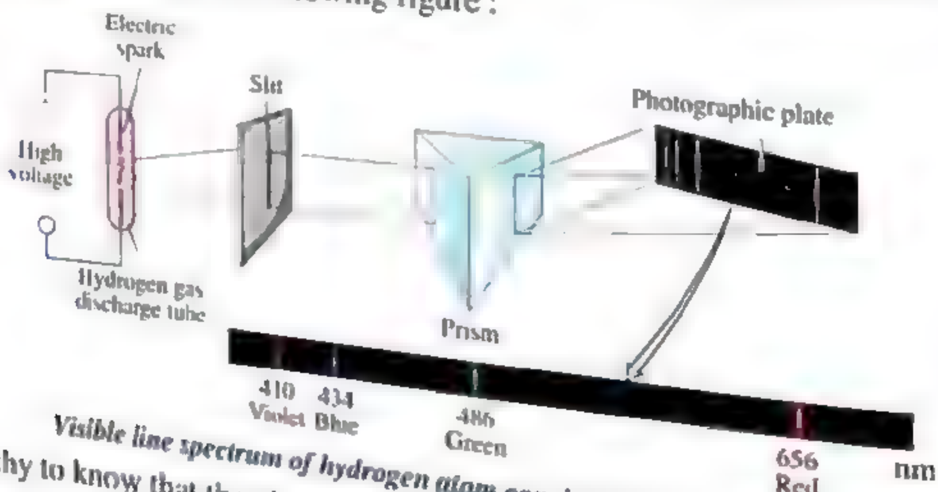
Until Before the quantum numbers

Atomic emission spectra

- On heating atoms of a pure element - in gaseous or vapor state - to high temperatures or exposing them to a low pressure inside an electrical discharge tube, they emit a radiation called emission spectrum (line spectrum).
- On examining this radiant light by a device called spectroscope, it was found that it is composed of a limited number of restricted colored lines separated by dark areas. So, it is called line spectrum.
- **The line spectrum is characteristic for each element,** this means there are no two elements with the same line spectrum, and this is due to the difference in the atomic number (number of protons) from one element to another.

Application **The line spectrum of hydrogen atom.**

- The line spectrum of hydrogen atom appears during examination as four colored lines separated by dark areas, as in the following figure :



Visible line spectrum of hydrogen atom consists of four coloured lines

- It is noteworthy to know that the physicists - at that time - were not able to explain this phenomenon.

Test Yourself

The line spectrum differs from an element to another due to ....

ⓐ the difference in the number of neutrons in each of them.

ⓑ the difference in the mass number of each of them.

ⓒ the difference in the electronic configuration of each of them.

ⓓ the difference in the number of valence electrons in each of them.

Idea of answering :

The difference in the line spectrum from an element to another is attributed to the difference in .... from an element to another, and consequently the difference of ....

Answer : The correct choice is ....

7 Bohr's atomic model (1913)

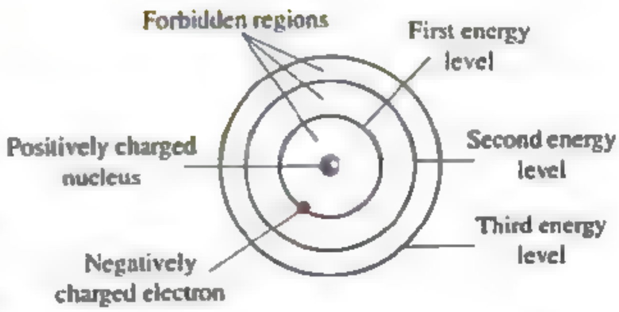
The study of atomic spectra is considered the key which solved the puzzle of the atomic structure. That was achieved by the Danish scientist Niels Bohr upon which he was rewarded the Nobel Prize in 1922

N. Bohr

Bohr's postulates

A Points that agree with Rutherford's postulates

1. A positively charged nucleus exists in the center of the atom.
2. The number of negative electrons (revolving around the nucleus) equals the number of positive protons inside the nucleus.
3. During the revolving of the electron around the nucleus, a centrifugal force arises which is equivalent to the attraction force of the nucleus on the electron.

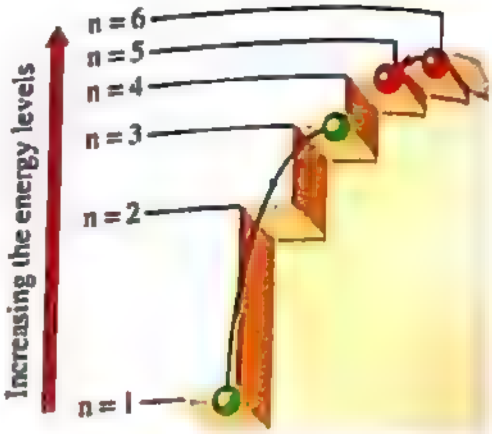


Bohr's model of atom

B New postulates

4. Electrons orbit the nucleus in a rapid movement without emission or absorption of any amount of energy and the atom in this case is named stable atom.

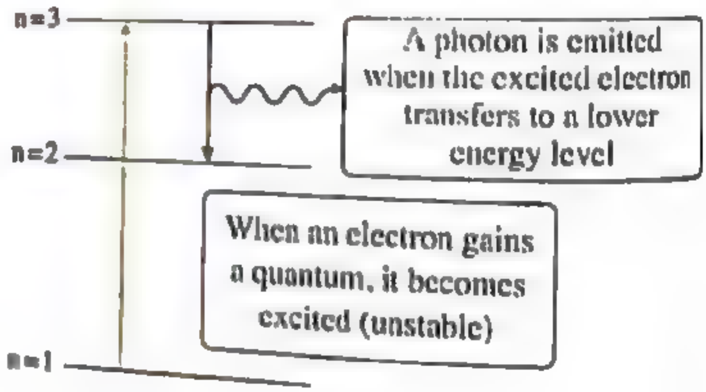
5. Electrons orbit the nucleus in definite allowed energy levels. They cannot be found in the regions between these levels, where the electron moves from an energy level to another one via a complete jump.



Electron transition from an energy level to another one takes place via a complete jump

6. Each electron in the atom has a definite amount of energy depending on the distance between its energy level and the nucleus, the energy of any level increases as its radius increases. Each energy level is expressed by an integer number called the principal quantum number (n), and the electron revolves in the lowest allowed energy level in its ground state.

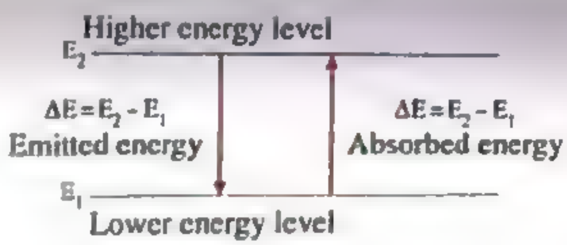
7. When the electron acquires a quantity of energy - known as quantum - by heating or by electric discharge, the electron jumps temporarily to a higher energy level. This is in case that the absorbed quantum of energy is equal to the difference in energies between the two levels, and the atom in this case is known as "excited atom". Since the electron in the excited atom is unstable, it returns back to its original level with emission of the same quantum of energy (photon) in the form of radiant light that appears in the form of a characteristic visible spectral line of a certain wavelength and frequency in addition to other invisible lines.



Common mistake

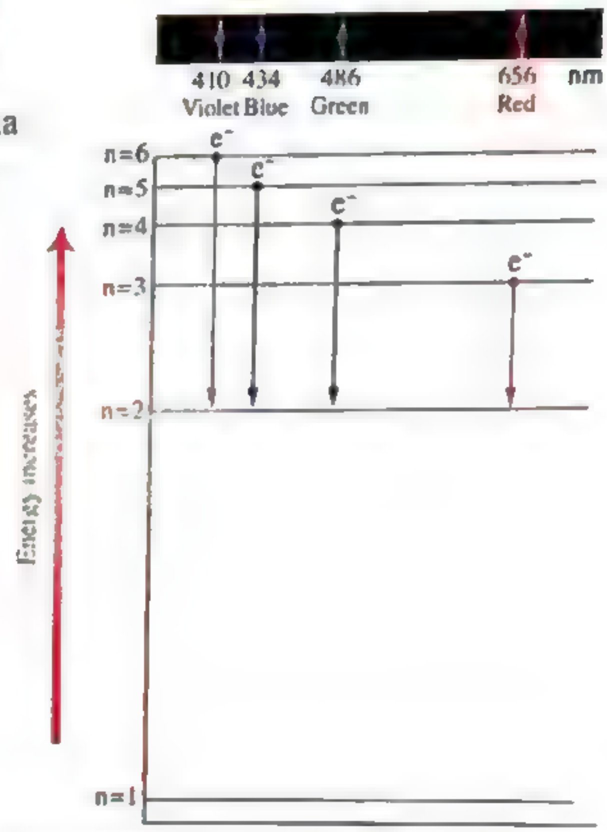
Presuming that the electron can gain or lose fractions of a quantum ($\frac{1}{4}$ quantum or $\frac{1}{2}$ quantum).

1 The acquired amount of energy (the quantum) when an electron transfers from its ground state to the excited state equals the amount of energy which is released when this electron returns back to its ground state level.



2 A lot of atoms absorb different amounts of energy (quanta) in the same time that a lot of excited atoms release other quanta producing spectral lines. These spectral lines indicate the energy levels from which their electrons are transmitted back to the ground state.

* The opposite figure represents the line spectrum of hydrogen atom which consists of four coloured lines indicating the higher energy levels from which the electrons transfer to the second energy level only.



The visible line spectrum of hydrogen atom consists of four coloured lines
(The wavelength of the visible spectrum ranges between 410 : 656 nm)

Worked Example

The spectral line of hydrogen atom consists of 4 coloured lines.
Which of these lines has the highest frequency ?

(a) Green. (b) Blue. (c) Red. (d) Violet.

Idea of answering :

∵ The wavelength is inversely proportional to the frequency.

∴ The frequency of the violet light is the highest, as its wavelength is lower than those of the other visible spectral lines.

Answer : The correct choice is (d)

Included information

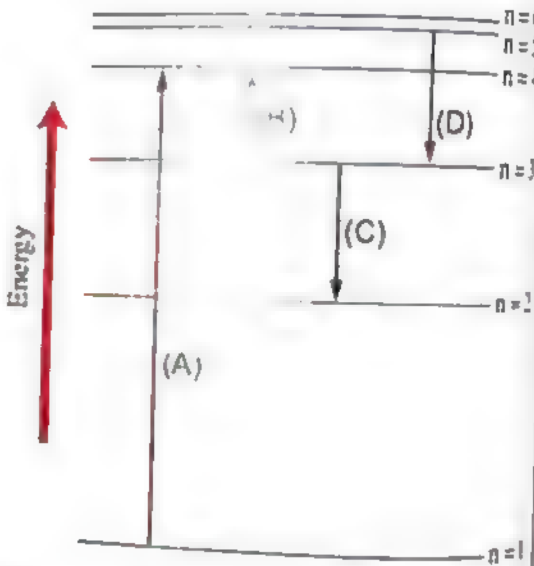
- Transferring the electron of hydrogen atom from higher energy levels to the lower energy levels forms series of electromagnetic radiations, **as shown in this table :**

Series	Electron transfer From (n)	To (n)	Spectrum region
First	2 , 3 , 4 , ...	1	Ultraviolet (Invisible)
Second	3 , 4 , 5 , ...	2	Visible spectrum
Third	4 , 5 , 6 , ...	3	Infrared (Invisible)
Fourth	5 , 6 , 7 , ...	4	

- The transference of the excited electron in hydrogen atom to its original energy level is accomplished by one jump or several successive jumps.

Worked Example

The opposite figure illustrates some travels of the electron of an excited hydrogen atom between the different energy levels.
Which of these travels produces a spectral line of hydrogen atom ?



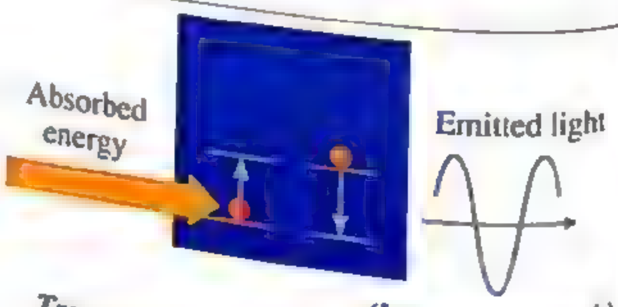
ⓐ A
ⓑ B
ⓒ C
ⓓ D

Idea of answering :
The spectral line of hydrogen atom is formed when the excited atom is transferred from higher energy levels to the second energy level only.

Answer : The correct choice is ⓒ

Notes

1. The amounts of energy required to transfer an electron between the different energy levels are not equal, because the distance and the difference in energy between them are not equal.



Transference of an electron between two close energy levels

❷ The quantum required to transfer an electron from an energy level to another decreases as we go farther from the nucleus,

because the energy gap decreases, as we go farther from the nucleus.

Transference of an electron between two distant energy levels

Test Yourself

What does happen to the spaces between energy levels on moving from (n = 1) to (n = 7) ?

ⓐ Decrease by increasing (n).

ⓑ Do not change.

ⓒ Increase by increasing (n)

ⓓ Change irregularly.

Answer : The correct choice is ..

Worked Example

Which of the following transfers of the electron of hydrogen atom is accompanied by releasing the largest amount of energy ?

ⓐ $n = 4 \longrightarrow n = 2$

ⓑ $n = 5 \longrightarrow n = 4$

ⓒ $n = 2 \longrightarrow n = 1$

ⓓ $n = 4 \longrightarrow n = 3$

Idea of answering :

∵ The difference in energy (the energy gap) between two consecutive energy levels decreases as the distance from the nucleus increases.

∴ The difference in energy between the second energy level (n = 2) and the first energy level (n = 1) is the highest.

Answer : The correct choice is ⓒ

The advantages and drawbacks of Bohr's atomic model

Despite the great efforts of Bohr to formulate his atomic model, the quantitative calculations of his theory didn't match all the experimental results.

Advantages (success) of Bohr's atomic model :

1. It explained the hydrogen spectral lines.
2. It introduced the idea of quantized energy to determine the electron energy in different energy levels in the atom.

Drawbacks of Bohr's atomic model :

The most important defects of Bohr's theory were the following :

1. It failed to explain the spectrum of any other element, except hydrogen atom which is the simplest electronic system, where it contains one electron only.
2. It considered the electron as a negative charged particle only and ignored its wave properties.
3. It presumed that it is possible to determine precisely both the location and speed of an electron at the same time, but in fact this is experimentally impossible.
4. It described the electron as a particle moving in a circular planar orbit, this means that hydrogen atom is planar. Later on, it was proved that the hydrogen atom has three dimensional coordinates.

Worked Example

Bohr's atomic model can be applied to ....

(a) Na^{10+} ion.

(b) He atom.

(c) Be^{2+} ion.

(d) C^{6+} ion.

Idea of answering :

∵ Bohr's atomic model can be applied to an atom (or an ion) that contains only one electron

∴ It can be applied to sodium ion which carries 10 positive charges Na^{10+}, as it contains only one electron (the atomic number of sodium is $_{11}Na$).

Answer : The correct choice is (a)

8 The principles of modern atomic theory (modified Bohr's model)

The modern atomic theory is based on some essential modifications of Bohr's model.

Among the most important modifications are the following :

A The dual nature of electron.

B The Heisenberg uncertainty principle.

C The wave-mechanical theory of the atom.

A The dual nature of electron

De Broglie

All the previously mentioned theories considered the electron just as a tiny negatively charged particle. However, all experimental data showed that the electron has a dual nature, as it is a material particle which also has wave properties.

The dual nature of electron

The electron is a material particle which has wave properties.

B The Heisenberg uncertainty principle

Heisenberg

Bohr's theory presumed that it is possible to determine both the location and velocity of the electron precisely at the same time, but by applying the principles of quantum mechanics, Heisenberg concluded that **"the determination of both the velocity and position of an electron at the same time is practically impossible.**
So, to speak in terms of "probability" seems to be more precise".
This is because the electron wave motion doesn't have a certain location.

Heisenberg uncertainty principle

The determination of both the velocity and position of an electron at the same time is practically impossible and this is subjected to the laws of probability.

Test Yourself

The approximate probable percentage of the possibility of determining the position and the speed of an electron whose mass is 9.1×10^{-31} kg together precisely is ....

ⓐ 0.0001% ⓑ 0.01%

ⓒ 0.1% ⓓ 1%

Answer : The correct choice is ....

C The wave-mechanical theory of the atom

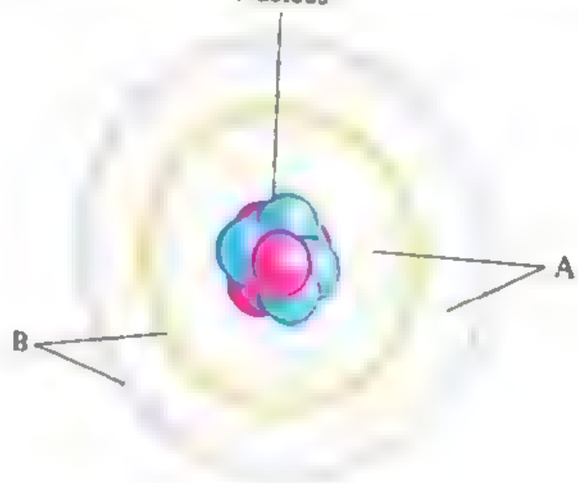
The Austrian scientist Schrödinger (1926) applied the ideas of Planck, Einstein, De Broglie and Heisenberg and could :

- Establish the wave-mechanical theory of the atom.
- Derive a wave equation that could be applied to the electron movement in the atom.

On solving Schrödinger's equation, it is possible to :

1. Determine the allowed energy levels.
2. Define the regions of space around the nucleus, where it is most probable to find the electron in each energy level.

- The wave-mechanical theory changed our concept about the movement of electron, where instead of speaking about the regions between the fixed circular orbits as being completely forbidden for the electrons, this theory introduced the concepts of :



Electron cloud

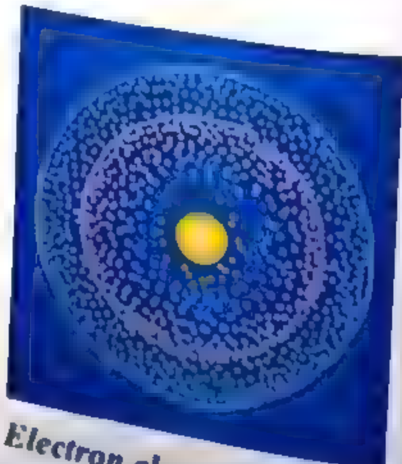
It is the region of space around the nucleus, in which the electron probably exists in all directions and distances (dimensions) (region A).

Orbital

It is the region within the electron cloud which has high probability of finding the electron (region B).

Application

- **Beryllium atom $_4Be$ contains :**
  - 2 electrons in level K
  - 2 electrons in level L

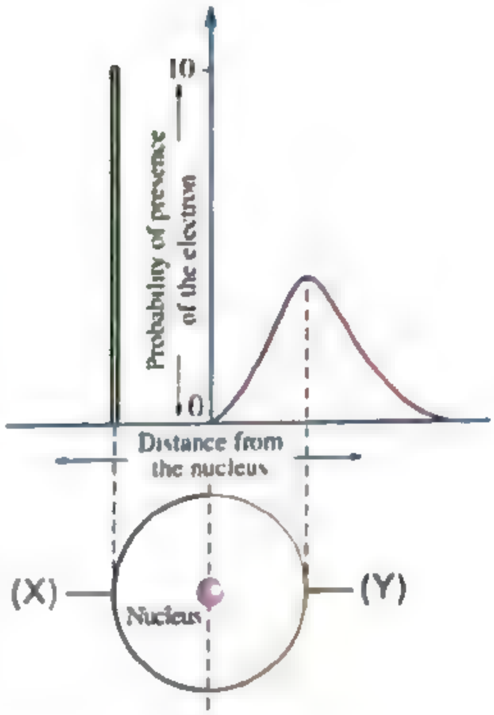


Electron cloud and orbital concepts in beryllium

Worked Example

What is the correct choice representing each of (X) and (Y) in the opposite figure ?

Choices	(X)	(Y)
(a)	Orbital	Orbital
(b)	Orbit	Electron cloud
(c)	Orbit	Orbital
(d)	Orbital	Orbit



Idea of answering :

∵ (X) indicates a definite level around the nucleus in which the electron can be found.

∴ (X) represents an orbit.

∴ The choices (a) and (d) are excluded.

∵ (Y) indicates a high probability of finding the electron.

∴ (Y) represents an orbital.

∴ The choice (b) is excluded.

Answer : The correct choice is (c)

Atomic model	Dalton's	Thomson's	Rutherford's	Bohr's	Modern atomic theory
Atom	• Solid indivisible particle • Masses of the atoms of the same element are similar, but they differ from one element to another.	• Solid sphere of uniform positive electric charges in which a number of negatively charged electrons are embedded resulting in making the atom neutral.	• Contains a vast space (not solid). • Electrically neutral.	• Contains a vast space (not solid) • Electrically neutral • Planar.	• Contains a vast space (not solid). • Electrically neutral.
Nucleus	Was not mentioned yet	Was not mentioned yet	• Positively charged. • Much smaller than the atom. • Most of the mass of the atom is contained in it.	• Positively charged. • Much smaller than the atom. • Most of the mass of the atom is contained in it.	• Positively charged. • Much smaller than the atom. • Most of the mass of the atom is contained in it.
Electrons	Were not mentioned yet	• Negatively charged particles embedded in the atom.	• Negatively charged particles, and their total negative charge equals the positive charge of the nucleus. • They move around the nucleus at tremendous speeds in special orbits. • Their mass is negligible compared to that of the nucleus.	• Negatively charged material particles (no wave properties yet). • They orbit the nucleus in definite orbits, and can not be found in the spaces between these orbits (forbidden regions). • The energy of the electron increases as the distance from the nucleus (the radius of its energy level) increases. • When an electron gains a quantum of energy, it jumps to a higher energy level and the stable atom [illegible]	• Material particles having wave properties (Dual nature of the electron). • It is not possible practically to determine both the velocity of an electron and its position at the same time, so this is described as probability distribution (uncertainty principle). • The region around the nucleus in which the electron probably exists in all dimensions is called the electron cloud. • The three dimensional region of space that indicates where there is a high probability of finding an electron is known as **the orbital.**
Additional information	The atoms of the different elements combine with each other in simple numerical ratios forming the compounds.		• This theory could not elucidate the system of revolving the electrons around the nucleus.	• This theory could not explain the line spectrum of any element atom other than hydrogen atom.	

Ready

Preliminary questions to remember the principal concepts in the lesson

Answer them yourself

Choose the correct answer for each of the following sentences :

(1) Who are the two scientists who agreed on that most of the atom is empty space ?

a. Geiger and Marsden.
b. Boyle and Dalton.
c. Thomson and Bohr.
d. Rutherford and Bohr.

(2) On heating gases or vapors to a high temperature under low pressure, they ....

a. absorb light.
b. emit visible or invisible rays.
c. emit gamma rays.
d. emit alpha particles.

(3) When an electron absorbs a quantum, it will transfer to ....

a. all higher energy levels.
b. all lower energy levels.
c. a higher energy level fits with the absorbed quantum.
d. a lower energy level fits with the absorbed quantum.

(4) When the electrons of an ex [illegible] original energy levels, this results in the emission of [illegible]

a. α-particles
b. β-particles
c. energy in the form of line spectra
d. γ-rays

(5) The dual nature of the electron means that it has

a. a mass and a charge.
b. a charge and a wave motion.
c. a volume and a wave motion.
d. a mass and a density.

(6) The scientist who presumed that it is possible to determine both the speed and position of an electron together precisely is ....

a. Heisenberg.
b. Thomson.
c. Bohr.
d. Boyle.

(7) What is the name of the scientist who destroyed Bohr's belief that there are regions in the atom that are forbidden for the electrons ?

a. Boyle.
b. Heisenberg.
c. Schrödinger.
d. De Broglie.

Atomic emission spectra (Line spectra)

The line spectrum of an element is characteristic, as no two elements can have the same ....

ⓐ atomic number.

ⓑ atomic mass.

ⓒ physical state.

ⓓ physical properties.

What is the scientific contribution which led to concluding the electron configuration of the elements ?

ⓐ Boyle's perception of the element.

ⓑ Analyzing the light emitted from the atoms when they acquire energy.

ⓒ Thomson's atomic model.

ⓓ Rutherford's atomic model.

All the following are correct, <u>except</u>

ⓐ the line spectrum of hydrogen atom is formed of four [illegible] colours.

ⓑ electrons have dual nature.

ⓒ Bohr's atomic model introduced the concept of quantum [illegible] the energy of the electrons.

ⓓ in case of not gaining or losing energy, the atom is described to be stable.

Bohr's atomic model

According to Bohr's theory, the orbit in which the electron revolves can be determined through ....

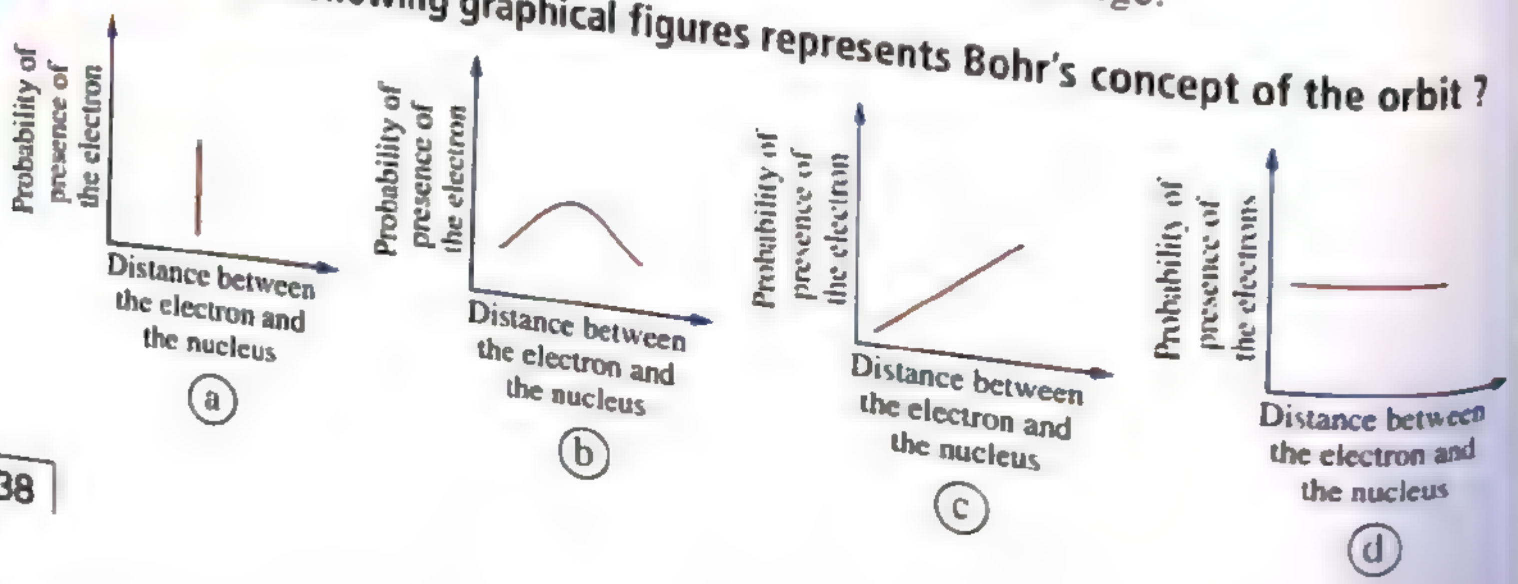
ⓐ the electron mass.

ⓑ the electron energy.

ⓒ the electron charge.

ⓓ the nucleus charge.

Which of the following graphical figures represents Bohr's concept of the orbit ?



6 **Through studying the line spectrum of an atom, it is possible to know ....**

ⓐ the isotopes of the element atom.

ⓑ the energy levels in the atom.

ⓒ the composition of the atom nucleus.

ⓓ the number of the neutrons inside the atom nucleus.

7 **Each of the following is correct for the electron, except ....**

ⓐ the electron in the lower energy level absorbs energy to transfer to a higher energy level.

ⓑ the amount of energy which is emitted from the excited electron equals the amount of energy which is absorbed by the same electron to reach the same state of excitement.

ⓒ the electron in the first energy level can be at infinite distance from the nucleus.

ⓓ electron can absorb different quanta of energy.

8 **The excited electron tends to ....**

ⓐ absorb energy to return to its ground state.

ⓑ produce light with a definite wavelength and energy.

ⓒ stay in its unstable state

ⓓ settle in a higher energy level

9 **On approaching one of lithium salts to the non-luminous region of bunsen flame, it acquires red colour, this is explained by that the electrons in the excited atoms of lithium ....**

ⓐ are lost from the atoms.

ⓑ their number increases.

ⓒ return to the ground state.

ⓓ transfer to higher levels.

10 **On comparing the position of the electron in its ground state, with its position in the excited state, it is ....**

ⓐ in the second energy level.

ⓑ in the nucleus.

ⓒ closer to the nucleus.

ⓓ farther from the nucleus.

11 **Which of the following supports the concept of quantum in determining the energy of the electrons ?**

(a) The emission spectrum of hydrogen atom.

(b) The cathode rays.

(c) Deflection of some α-particles on colliding with gold foil.

(d) Penetration of most of α-particles on colliding with gold foil.

12 **According to Bohr's atomic model, to travel from the first level K to the fourth level N, the electron ....**

(a) acquires a quantum.

(b) loses a quantum.

(c) acquires 4 quanta.

(d) loses 4 quanta.

13 **The visible line spectrum of hydrogen atom arises as a result of the return of the excited electron from higher energy levels to the level ....**

(a) K

(b) L

(c) M

(d) N

14 **Which of the following transitions of the electron in hydrogen atom results in the emission of visible light ?**

(a) $(n = 5) \longrightarrow (n = 2)$.

(b) $(n = 3) \longrightarrow (n = 1)$.

(c) $(n = 5) \longrightarrow (n = 3)$.

(d) $(n = 6) \longrightarrow (n = 3)$.

15 **Which of the following transitions in hydrogen atom results in the emission of a visible light with the shortest wavelength ?**

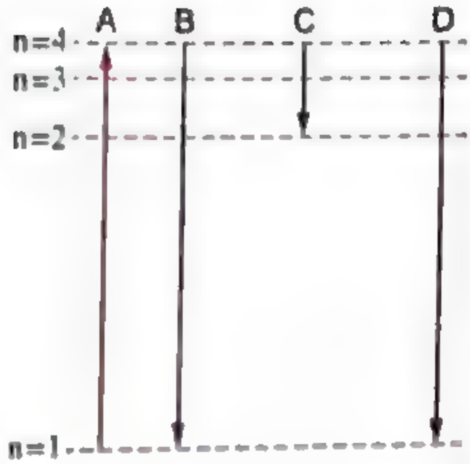
(a) $(n = 5) \longrightarrow (n = 2)$.

(b) $(n = 6) \longrightarrow (n = 2)$.

(c) $(n = 3) \longrightarrow (n = 5)$.

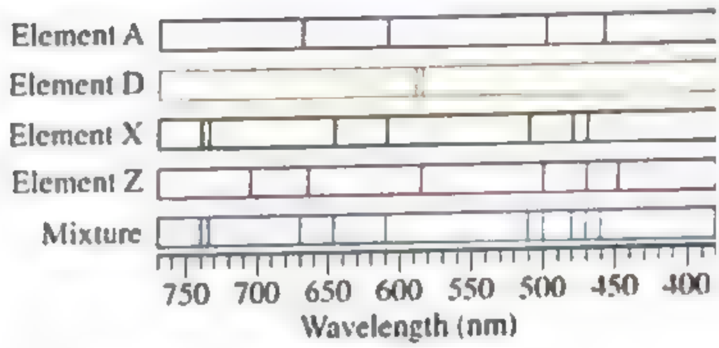
(d) $(n = 6) \longrightarrow (n = 1)$.

16 The opposite figure shows several travels of the electron of an excited hydrogen atom between its different energy levels.
Which of these travels produces a spectral line of hydrogen atom ?



ⓐ A
ⓑ B
ⓒ C
ⓓ D

17 The opposite figure shows the line spectra of four elements A, D, X and Z in addition to a mixture of two of these elements.
What are the two elements which are found in the mixture ?



ⓐ (D) and (A).
ⓑ (X) and (A).
ⓒ (D) and (Z).
ⓓ (X) and (Z).

18 In the excited hydrogen atom, a photon of light with wavelength 486 nm is emitted when an electron transfers from the principal level (n = 4) to the principal level ....

ⓐ n = 1
ⓑ n = 2
ⓒ n = 3
ⓓ n = 5

19 Each line in the line spectrum of lithium atom represents ....

ⓐ the energy absorbed by the atom when it loses an electron.
ⓑ the energy absorbed by the atom when it gains an electron.
ⓒ the energy released when an electron transfers from a lower energy level to a higher energy level.
ⓓ the energy released when an electron transfers from a higher energy level to a lower energy level.

20 The spectral lines of the atom of any element indicate ....

ⓐ the number of electrons in the atom of this element.
ⓑ the energy level where the electron is present.
ⓒ the energy of the electron in the energy level.
ⓓ the difference in energy between two energy levels.

21 The ray whose wavelength is 486 nm lies in the ....

(a) infrared region.
(b) ultraviolet region.
(c) visible region.
(d) infraviolet region.

22 The visible line spectrum of hydrogen atom consists of four coloured lines. Which of them has the smallest frequency ?

(a) The green.
(b) The blue.
(c) The red.
(d) The violet.

23 The electron in hydrogen atom which is excited to the fourth energy level ....

(a) remains in the same new energy level.
(b) returns to its ground state accompanied by visible spectrum only.
(c) returns to its ground state in one jump or several successive jumps.
(d) transfers to a higher energy level.

Questions marked by this mark their ideas are explained in the answers

24 If the difference in energy between energy levels K and L equals ΔE_1 then the difference in energy ΔE_2 between energy levels O and P is ....

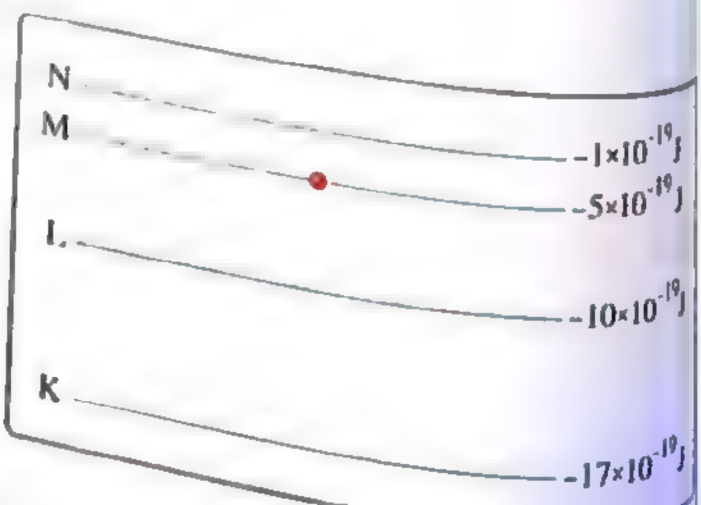
(a) higher than ΔE_1
(b) lower than ΔE_1
(c) equal to ΔE_1
(d) approximately ΔE_1

25 If an electron acquires an amount of energy equals 1.89 eV to transfer from energy level L to M, then to transfer from L to K, it may ....

(a) lose an amount of energy equals 1.89 eV
(b) acquire an amount of energy equals 1.89 eV
(c) lose an amount of energy equals 1.89 eV
(d) acquire an amount of energy equals 10.2 eV
(e) lose an amount of energy equals 10.2 eV

26 In the opposite figure, if an electron in the energy level M in a hypothetical atom acquires an amount of energy equals 3×10^{-19} J, then it ....

(a) transfers to the level L
(b) transfers to the level K
(c) transfers to the level N
(d) remains in the level M



27 **Among the postulates of Bohr's atomic model is that ....**

ⓐ electrons can acquire any amount of energy.

ⓑ it is impossible to determine the path of the electrons precisely.

ⓒ the energies of the electrons in different energy levels are determined through the concept of quantum.

ⓓ the electron has a dual nature.

28 **Which of the following statements is consistent with Bohr's postulates ?**

ⓐ Space regions between energy levels are occupied by electrons.

ⓑ The atom has no dimensions or spatial directions.

ⓒ The electron is a negative particle with wave properties.

ⓓ The electron revolves around the nucleus in all directions.

29 **Bohr's atomic model differs from that of Rutherford, this difference is obvious in Bohr's postulate that the electron ....**

ⓐ produces a spectral line when it loses a quantum.

ⓑ is a negatively charged particle.

ⓒ does not produce a spectral line when it loses a quantum.

ⓓ revolves around the nucleus in certain orbits.

The modern atomic theory

30 **Which of the following electronic transitions in hydrogen atom is accompanied by releasing the largest amount of energy ?**

ⓐ From the orbit M to the orbit L and the position of this electron can be determined.

ⓑ From the orbit N to the orbit M and neither the position nor the speed of this electron can be determined precisely.

ⓒ From the orbit L to the orbit K and this electron has a dual nature.

ⓓ From the orbit L to the orbit K and the position and the speed of this electron can be determined precisely.

31 **Each of the following is among the properties of the electron, except that it ....**

ⓐ is a material particle.

ⓑ has wave properties.

ⓒ loses energy when it transfers from one energy level to a higher level.

ⓓ deflects by the effect of a magnetic field.

32 **The following statements represent the attempts to develop the atomic model in no particular order :**

- **A** : The electron has wave properties in addition to being a particle.
- **B** : The atom contains tiny negatively charged particles.
- **C** : In the center of the atom, a small nucleus is found which is relatively of high density.
- **D** : The atom is solid and indivisible.

What is the correct sequence of these attempts ?

ⓐ C ⟶ D ⟶ A ⟶ B

ⓑ C ⟶ D ⟶ B ⟶ A

ⓒ D ⟶ B ⟶ A ⟶ C

ⓓ D ⟶ B ⟶ C ⟶ A

33 **Which of the following statements is a Heisenberg's modification to Bohr's atomic model ?**

ⓐ It is difficult to determine the position and the speed of the electron together precisely.

ⓑ Space regions between energy levels are not forbidden for the electrons.

ⓒ The electron is a particle with wave properties.

ⓓ Both the speed and the position of the electron can be determined together precisely.

34 **"The actual position of the last electron in iron atom and its speed in a certain moment can not be precisely determined".**
The previous statement is an application of ....

ⓐ Hund's rule.

ⓑ Bohr's model.

ⓒ uncertainty principle.

ⓓ the dual nature of the electron.

35 **According to the wave-mechanical theory, ...**

ⓐ the electron has a mass as well as wave properties.

ⓑ the electrons are found in the orbitals.

ⓒ the nucleus is very small compared to the atom.

ⓓ the electrons are negatively charged.

36 **The modern atomic theory agrees with Rutherford's model on that ....**

ⓐ the atom is not solid.

ⓑ the electrons have wave properties.

ⓒ it is impossible to determine the speed and the position of the electron together precisely.

ⓓ there is a pattern according to which the electrons orbit the nucleus.

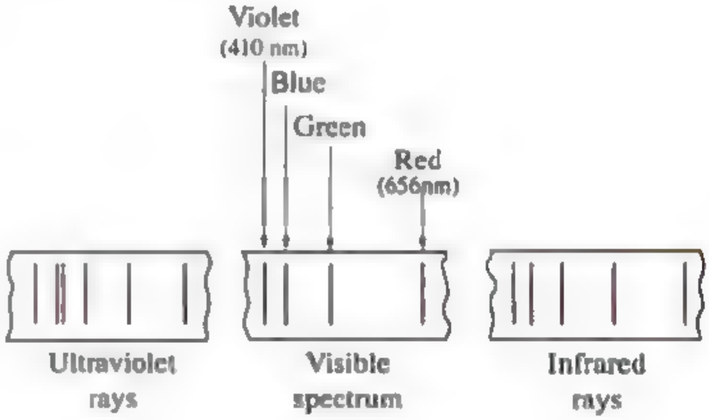
Essay questions

37 In the opposite figure, **determine with explanation** the position(s) in which is (are) impossible for the electron to be present according to Bohr's atomic model.

38 **Which is higher in frequency – with explanation –** the red light or the infrared rays ?

39 **Why is it called** ultraviolet rays, while the violet light is called so ?

40 The opposite figure represents a part of the components of the electromagnetic spectrum.
Why are the ultraviolet rays and the infrared [illegible]



41 In the light of your understanding for Bohr's atomic model.
Show the change which occurs in each of the energy and the position of an electron when it is excited.

42 The opposite table represents the probabilities of the emission spectrum of hydrogen atom.
Which of these probabilities represents the visible spectrum of hydrogen atom ? Give reason.

Probability	Electron transfer	
	From (n)	To (n)
(A)	2, 3, 4, 5	1
(B)	3, 4, 5, 6	2
(C)	4, 5, 6, 7	3

43 **The two opposite figures represent two different perceptions for the movement of the electrons around the nucleus, predict :**

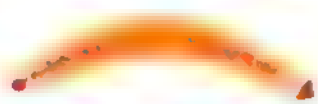


Figure (X)

Figure (Y)

(1) The name of the scientist who suggested the perception which is illustrated in the figure (Y).

(2) The scientific term that represents the region in which the electron can be found in the figure (X).

Quantum numbers

The mathematical solution of Schrödinger's equation [illegible] numbers that were called quantum numbers.

To determine the energy of an electron in multi-electron [illegible] should know the four quantum numbers which describe it, these four [illegible] :

1. **The principal quantum number (n) :**
   It describes the distance of the electron from the nucleus.

2. **The subsidiary quantum number (l) :**
   It describes the shapes of electron cloud in the sublevels.

3. **The magnetic quantum number (m_l) :**
   It describes the shape and number of the orbital in which the electron exists.

4. **The spin quantum number (m_s) :**
   It describes the spin motion of the electron.

1 The principal quantum number (n)

- It is used to define the following :
  - The order of principal energy levels or electron shells «Their number in the heaviest known atom in its ground state is seven».
  - The number of electrons (e^-) required to fill a given principal energy level from the relation $2n^2$
    (i.e. it equals two times the square of the shell number indicated by the letter "n").

Order of the level (n)	The number of electrons required to fill the energy level ($2n^2$)
1	$2 \times 1^2 = 2$ electrons
2	$2 \times 2^2 = 8$ electrons
3	$2 \times 3^2 = 18$ electrons
4	$2 \times 4^2 = 32$ electrons

- The rule $2n^2$ isn't applied to the energy levels higher than the fourth level, because the atom becomes unstable, if the number of electrons exceeds 32 electrons in any level.
- The principal quantum number has a positive integer numerical values 1 , 2 , 3 , 4 , ... etc, (excluding zero). Each value is expressed by an alphabetical letter that represents a principal energy level as shown in the following table :

Number of the level (n)	1	2	3	4	5	6	7
Symbol of the level	K	L	M	N	O	P	Q

K L M N O P Q

Energy of the level increases from K to Q

2 The subsidiary quantum number (ℓ)

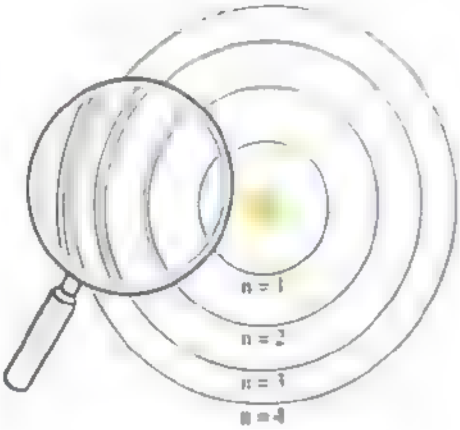
- It determines the energy sublevels within each principal energy level.
- Each principal energy level consists of a number of energy sublevels which are represented by whole numerical values which range between [0 : (n – 1)], and their number equals its principal quantum number.

> **Note**
>
> Real energy levels in the atom are called energy sublevels

- The energy sublevels take the symbols and values as shown in the following table :

Subsidiary quantum number (ℓ) values [0 : (n – 1)]	0	1	2	3
Symbols of sublevels	*s*	*p*	*d*	*f*

The following table shows the relation between the principal quantum number (n) for each energy level and the number of the possible values of the subsidiary quantum number (ℓ), where [(n) value = The number of (ℓ) values] :



Energy sublevels in each principal energy level

Symbol of the principal energy level	Principal quantum number (n)	Symbols of the sublevels	Values of the subsidiary quantum number (ℓ)
K	1	1s	0
L	2	2s	0
		2p	1
M	3		0
			1
			2
N	4		0
		4p	1
		4d	2
		4f	3

* It is observed that there is a small difference in the energy of the sublevels in each principal energy level.
* They can be arranged according to increasing their energy in the following order :

$$s < p < d < f$$

Worked Examples

1 What are the probable (ℓ) values when (n = 3) ?

ⓐ 0 or 1 ⓑ 0 or 3 ⓒ 0 , 1 or 2 ⓓ 0 , 2 or 3

Idea of answering :

∵ Each principal energy level consists of a number of sublevels which equals its numerical value.

∴ No. of the sublevels = 3

∴ The choices ⓐ and ⓑ are excluded.

∵ The probable (ℓ) values range between [0 : (n – 1)].

∴ The probable (ℓ) values when (n = 3) range between [0 : (3 – 1)] = 0 , 1 or 2

Answer : The correct choice is ⓒ

2 **In which of the following levels can the electron absorb a photon but can not lose one ?**

ⓐ $3d$ ⓑ $2p$ ⓒ $1s$ ⓓ $2s$

Idea of answering :

* When an electron loses a photon (an amount of energy), it transfers to a lower energy level (closer to the nucleus).

∵ The first energy level is the closest to nucleus, and it consists of only one energy sublevel which is $1s$

∴ The electron in the sublevel $1s$ can absorb a photon to travel to a higher energy level, but it can not lose a photon.

Answer : The correct choice is ⓒ

Test Yourself

Which of the following energy sublevels does not actually exist ?

ⓐ $2p$

ⓑ $3d$

ⓒ $5d$

ⓓ $3f$

Answer : The correct choice is ....

3 The magnetic quantum number (m_l)

- It determines the number of orbitals within a certain energy sublevel from the relation : $(2\ell + 1)$.
- It determines the spatial orientations (directions in space) of orbitals.
- It is represented by odd number of integer numerical values ranging between $(-\ell, \dots, 0, \dots, +\ell)$.

The following table shows the relation between (ℓ) values and the probable values of the magnetic quantum number (m_ℓ) for the electrons of the first four energy levels :

Values of principal quantum number (n)	Values of subsidiary quantum number (ℓ) [0 : (n – 1)]	Symbols of energy sublevels	Values of the magnetic quantum number (m_ℓ) ($-\ell$, ..., 0, ..., $+\ell$)	Number of the sublevel orbitals ($2\ell + 1$)	Number of the principal level orbitals (n^2)
1	0	*1s*	0	1	1
2	0	*2s*	0	1	4
	1	*2p*	–1 , 0 , +1	3	
3	0	*3s*	0	1	9
	1	*3p*	–1 , 0 , +1	3	
	2	*3d*	–2 , –1 , 0 , +1 , +2	5	
4	0	*4s*	0	1	16
	1	*4p*	–1 , 0 , +1	3	
	2	*4d*	–2 , –1 , 0 , +1 , +2	5	
	3	*4f*	–3 , –2 , –1 , 0 , +1 , +2 , +3	7	

Test Yourself

1. What are the probable (m_ℓ) values when ($\ell = 2$) ?

ⓐ 0 , +1 and +2 only.

ⓑ 0 , –1 and –2 only.

ⓒ –2 , –1 , 0 , +1 and +2

ⓓ –3 , –2 , –1 , 0 , +1 , +2 and +3

Idea of answering :

∵ The probable (m_ℓ) values range between $-\ell$, . . . , 0 , . . . , $+\ell$

∴ The probable (m_ℓ) values when ($\ell = 2$) are ....

Answer : The correct choice is ....

❷ Which of the following possibilities of quantum numbers of an electron includes a mistake ?

ⓐ $n = 3$, $l = 2$, $m_l = -1$

ⓑ $n = 4$, $l = 3$, $m_l = -2$

ⓒ $n = 1$, $l = 1$, $m_l = +1$

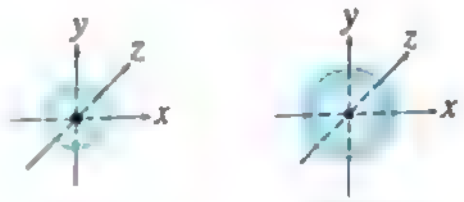
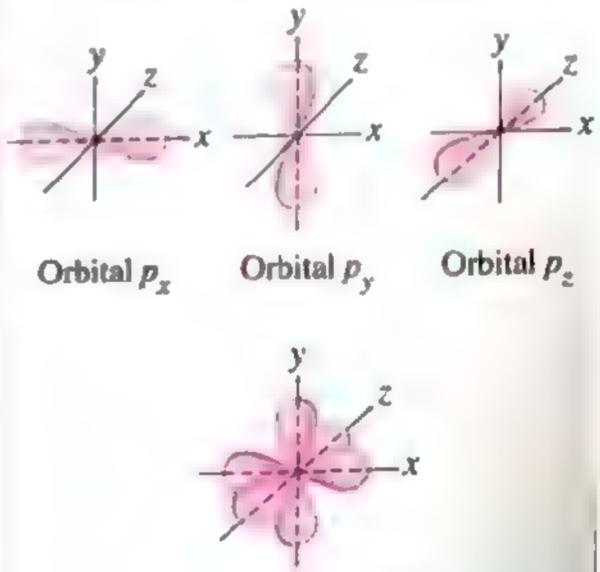
ⓓ $n = 2$, $l = 0$, $m_l = 0$

Idea of answering :

When ($n = 1$), then the value of each of (l) and (m_l) will be .... only.

Answer : The correct choice is ....

* The orbitals of the same sublevel are equal in energy and similar in shape, but differ in the direction in space as shown in the following table :

Sublevels	Number of orbitals	Shape in space (electron density)	Figure
s	1	Sphe[illegible] symmetrical shape around the nucleus.	 Orbital $1s$ Orbital $2s$
p	3	• Each orbital takes the form of two [illegible] to head (dumb-bell shaped) at a point of zero electron density (node). • Each orbital is perpendicular to the two other orbitals. • The axes of the three orbitals take the three spatial orientations, thus they are designated as p_x , p_y and p_z	 Orbital p_x Orbital p_y Orbital p_z
d	5	Complicated shapes	
f	7		

- Any orbital cannot be occupied by more than two electrons $2e^-$, each of them rotates around its own axis while revolving around the nucleus (like the earth which rotates around its own axis while revolving around the sun).

Each orbital is filled with 2 electrons :

Sublevel	*s*	*p*	*d*	*f*
Number of orbitals	1	3	5	7
Electron capacity	2	6	10	14

Note

p sublevel becomes saturated with $6e^-$, while *d* sublevel becomes saturated with $10e^-$, because *p* sublevel contains 3 orbitals, while *d* sublevel contains 5 orbitals and each orbital is filled completely with $2e^-$

Worked Examples

1 The orbitals in the same sublevel are different in ....

(a) the distance from the nucleus.

(b) the magnetic quantum number.

(c) shape and size.

(d) the subsidiary quantum number.

Idea of answering :

∵ The orbitals in the same sublevel have the same principal quantum number.

∴ They are at the same distance from the nucleus.

∴ The choice (a) is excluded.

∵ The values of the magnetic quantum number (m_l) of the orbitals in the same sublevel range between ($-l$, ... , 0 , ... , $+l$)

∴ The orbitals in the same sublevel are different in the magnetic quantum number.

Answer : The correct choice is (b)

2 **The following figures illustrate the probable electron cloud of the electron of the excited hydrogen atom in two different cases :**

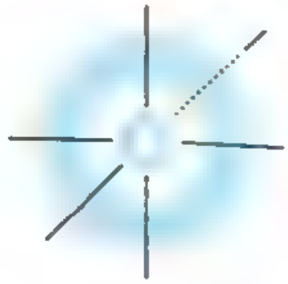


Figure (1)

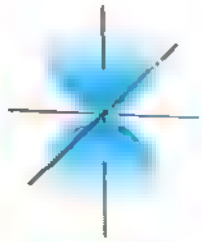


Figure (2)

What is the principal quantum number (n) which is not probable for the electron in both cases ?

ⓐ 1 ⓑ 2 ⓒ 3 ⓓ 4

Idea of answering :

∵ The figures illustrate the probable electron cloud of the electron of an excited hydrogen atom in two different cases.

∴ The electron has already transferred from the first principal energy level (n = 1) to a higher level.

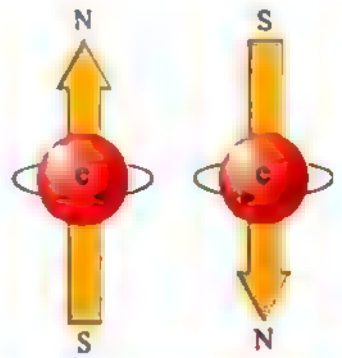
∴ The principal quantum number of this electron is not probable to be (n = 1) in any of these cases.

Answer : The correct choice is

4 The spin quantum number

Any orbital cannot be occupied by more than two electrons, each electron spins on its own axis during its orbiting around the nucleus.

* The spin quantum number defines the type of spin motion of the electron around its axis in the orbital, which is either :
  • Clockwise (↑) with m_s value equals $(+\frac{1}{2})$.
  • Anticlockwise (↓) with m_s value equals $(-\frac{1}{2})$.



The spin motions of the two electrons of the same orbital

* The spin motion of the electron around its own axis in a certain direction results in arising a magnetic field.

* The opposite spin motion of the two electrons of the same orbital around their own axes results in arising two magnetic fields in two opposite directions (spin-paired state) (⇅).

★ **Orbitals have three different possibilities depending on the number of electrons located in them as follows :**

□	Empty orbital.
↑	Half filled orbital contains one electron.
↑↓	Completely filled orbital contains 2 paired electrons that have opposite spinning directions (spin-paired state).

Note

Although the two electrons of the same orbital carry the same negative charge, they don't repel each other, because the magnetic field which arises from the spinning of one electron is in a direction opposing the direction of the other magnetic field arising from the spinning of the other electron and that decreases the repulsive force between the two electrons.

Worked Example

Two electrons in the same atom lie in the second orbital in the same sublevel *p* in the same principal level M
Write the four quantum numbers of the two electrons.

Idea of answering :

∵ The principal level is M

∴ The principal quantum number (n) of each of them is 3

∵ The sublevel is *p*

∴ The secondary (subsidiary) quantum number (ℓ) of each of them is 1

∵ They both lie in the second orbital.

∴ The magnetic quantum number (m_ℓ) of each of them is 0

∵ The two electrons in the same orbital are opposite in spin motion.

∴ The spin quantum number (m_s) of one of them is ($+\frac{1}{2}$) and that of the other is ($-\frac{1}{2}$).

Answer :

The four quantum numbers	n	ℓ	m_ℓ	m_s
First electron	3	1	0	$+\frac{1}{2}$
Second electron	3	1	0	$-\frac{1}{2}$

Summary of the quantum numbers

Quantum number	Principal (n)	Subsidiary (ℓ)	Magnetic (m_ℓ)	Spin (m_s)
Used in the determination of	* **The order of the principal energy levels.** "Their number in the heaviest known atom is 7". K L M N O P Q 1 2 3 4 5 6 7 * **The number of the electrons required to saturate each principal energy level from the relation :** $\boxed{2n^2}$	* Energy **sublevels** in each principal energy level. "Each principal energy level (**n**) contains a number of energy sublevels (ℓ) that equals the numerical value of (**n**)". Sublevel – Value of (ℓ) *s* – 0 *p* – 1 *d* – 2 *f* – 3	* Number of the orbitals in each **principal energy level (n)** from the relation : $\boxed{n^2}$ * **Number of the orbitals** in each energy sublevel (ℓ) from the relation : $\boxed{2\ell + 1}$ * The spatial orientations of the orbitals. **Each orbital is filled with 2 electrons**	* **The direction of motion** of the electron around its axis (spin motion) : • Either clockwise (↑) its numerical value is $(+\frac{1}{2})$. • Or anticlockwise (↓) its numerical value is $(-\frac{1}{2})$.
Application	* **The third** principal energy level M becomes **saturated** with a number of electrons equals $\boxed{2 \times 3^2 = 18e^-}$	* The third principal energy level M consists of : **Three** energy **sublevels** which are : $\boxed{s, p, d}$	* **The third** principal energy level M consists of number of **orbitals** equals $\boxed{3^2 = 9}$ * Sublevel ***p*** whose value is 1 consists of a number of **orbitals** equals $\boxed{(2 \times 1) + 1 = 3}$	* When the sublevel *d* contains 8 electrons, then **the first** electron in it will spin around its axis **clockwise**, and its (m_s) value will be $(+\frac{1}{2})$. $\boxed{\uparrow}\boxed{}\boxed{}\boxed{}\boxed{}$ While, **the last** electron in it will spin around its axis **anticlockwise**, and its (m_s) value will be $(-\frac{1}{2})$. $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow}$

Summary of the relations between the principal level, the sublevels and the orbitals

Symbol of the principal level	Principal quantum number (n)	The sublevels in each principal level	Secondary quantum number (l)	No. of the orbitals in each sublevel ($2l+1$)	No. of the orbitals in each principal level (n^2)	No. of the electrons required to saturate each principal level ($2n^2$)
K	1	1s	0	1	1	$2 \times 1 = 2e^-$
L	2	2s	0	1	4	$2 \times 4 = 8e^-$
		2p	1	3		
M	3	3s	0	1	9	$2 \times 9 = 18e^-$
		3p	1	3		
		3d	2	5		
N	4	4s	0	1	16	$2 \times 16 = 32e^-$
		4p	1	[illegible]		
		4d	2	5		
		4f	3	7		

Ready

Preliminary questions to remember the principal concepts in the lesson

Answer them yourself

Choose the correct answer for each of the following sentences :

(1) The maximum possible value of the principal quantum number (n) in the heaviest known atom in its ground state is ....

a. 5 b. 6

c. 7 d. 8

(2) The maximum number of electrons that saturates the principal energy level (n) is given from the rule ....

a. 2n b. n^2

c. $2n^2$ d. $(2n)^2$

(3) What is the quantum number whose value may never be zero or a fraction ?

a. Principal. b. Subsidiary.

c. Magnetic. d. Spin.

(4) The principal quantum number (n) of the electron of the sublevel $3s^1$ equals ....

a. 0 b. 1

c. 2 d. 3

(5) The symbols s, p, d, f indicate ....

a. principal energy levels.

b. energy sublevels.

c. the number of orbitals of the sublevel.

d. the number of single electrons in the individual sublevel.

(6) What is the symbol of the principal level which contains s, p and d only ?

a. L b. M

c. N d. K

(7) When (n = 2), then one of the possible values of the subsidiary quantum number is ....

a. –2

b. 0

c. $\frac{1}{2}$

d. 2

(8) What is the quantum number whose value for an electron in the principal level (L) is –1 ?

a. Principal.

b. Subsidiary.

c. Magnetic.

d. Spin.

(9) The number of orbitals in each principal energy level (n) equals ....

a. n^2

b. $n - 1$

c. $3n^2$

d. $2n^2$

(10) The number of orbitals of the principal level N equals ....

a. 1

b. 9

c. 14

d. 16

(11) The orbitals in the same sublevel are ....

a. different in energy.

b. equal in energy.

c. different in shape.

d. different in size.

(12) What is the maximum number of electrons required to saturate one orbital in 4*f* sublevel ?

a. $2e^-$

b. $7e^-$

c. $10e^-$

d. $14e^-$

(13) What are the similar quantum numbers between the 2 electrons of the two orbitals $2p_x^1$, $2p_z^1$?

a. n , m_s , ℓ

b. n , m_ℓ , ℓ

c. n , m_s

d. n , ℓ , m_ℓ , m_s

(14) Which of the following quantum numbers its (their) values are never negative ?

a. n only.

b. ℓ only.

c. m_ℓ , m_s

d. n , ℓ

Multiple choice questions

1 **What are the three quantum numbers which are relied on, to solve the wave equation to explain the behavior of the electron in hydrogen atom ?**

(a) n , ℓ , m_s
(b) m_ℓ , m_s , m_p
(c) n , ℓ , m_ℓ
(d) ℓ , m_ℓ , m_s

2 **When the electron in hydrogen atom transfers from *4d* to *2s*, the emitted photon is in the form of**

(a) infrared ray.
(b) ultraviolet ray.
(c) visible light.
(d) X ray.

3 **All the following describe the sublevel *s* , except that**

(a) it is found in all principal energy levels of the atom.
(b) its size increases by increasing [illegible]
(c) its electron capacity increase [illegible] the value of n.
(d) its shape does not change [illegible] value of n.

4 **What is the sublevel in which the two quantum numbers of the last electron are $(n = 2 , \ell = 0)$?**

(a) *2s*
(b) *2p*
(c) *1s*
(d) *3p*

5 **Which of the following can be concluded from the relation : $2\ell + 1 = 5$?**

(a) This sublevel is saturated with 10e
(b) This sublevel is found in the second principal energy level.
(c) The maximum value of the magnetic quantum number of the electrons of this sublevel is -3
(d) The maximum number of electrons which saturate this sublevel is 5e

6 **The electron which has the two quantum numbers, $(n = 3 , m_\ell = +2)$ must have the value ....**

(a) $m_s = +\frac{1}{2}$
(b) $\ell = 1$
(c) $\ell = 0$
(d) $\ell = 2$

7 **Which of the following represents an electron in an atom ?**

It is found in ....

ⓐ the principal energy level L , and its subsidiary quantum number is 2

ⓑ the principal energy level K , and its magnetic quantum number is +1

ⓒ the principal energy level M , and its subsidiary quantum number is 2

ⓓ the sublevel *d*, and its principal quantum number is 2

8 **What is the maximum number of electrons which can be found in the same atom and have the two quantum numbers ($n = 4$, $\ell = 1$) ?**

ⓐ $2e^-$
ⓑ $6e^-$
ⓒ $8e^-$
ⓓ $10e^-$

9 **What is the maximum number of electrons which have the spin quantum number ($m_s = +\frac{1}{2}$) in the sublevel ($\ell = 3$) ?**

ⓐ $3e^-$
ⓑ $5e^-$
ⓒ $7e^-$
ⓓ $14e^-$

Questions marked by this mark their ideas are explained in the answers

10 **Number of electrons required to saturate each sublevel is estimated from the relation ....**

ⓐ $2(2\ell + 1)$
ⓑ $(2\ell + 1)$
ⓒ $2n^2$
ⓓ n^2

11 **Which of the following quantum numbers values represent an electron in the orbital $3p_x$?**

ⓐ $n = 3$, $\ell = 2$, $m_\ell = -1$
ⓑ $n = 3$, $\ell = 0$, $m_\ell = 0$
ⓒ $n = 3$, $\ell = 0$, $m_\ell = +1$
ⓓ $n = 3$, $\ell = 1$, $m_\ell = -1$

12 **Which of the following quantum numbers values represent an electron in one of the orbitals of $5f$ sublevel ?**

ⓐ $n = 5$, $\ell = 3$, $m_\ell = +4$, $m_s = +\frac{1}{2}$

ⓑ $n = 5$, $\ell = 2$, $m_\ell = -2$, $m_s = +\frac{1}{2}$

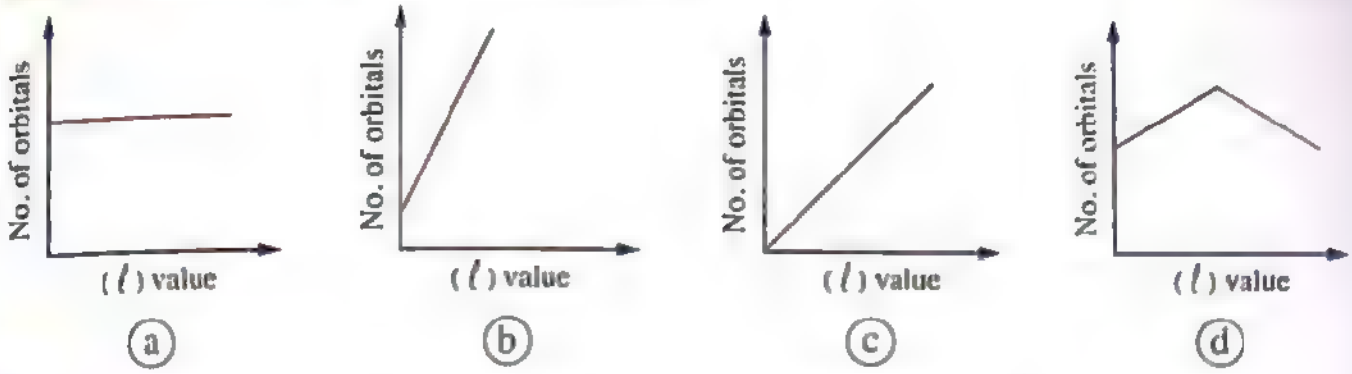
ⓒ $n = 5$, $\ell = 3$, $m_\ell = +1$, $m_s = +\frac{1}{2}$

ⓓ $n = 5$, $\ell = 4$, $m_\ell = -4$, $m_s = -\frac{1}{2}$

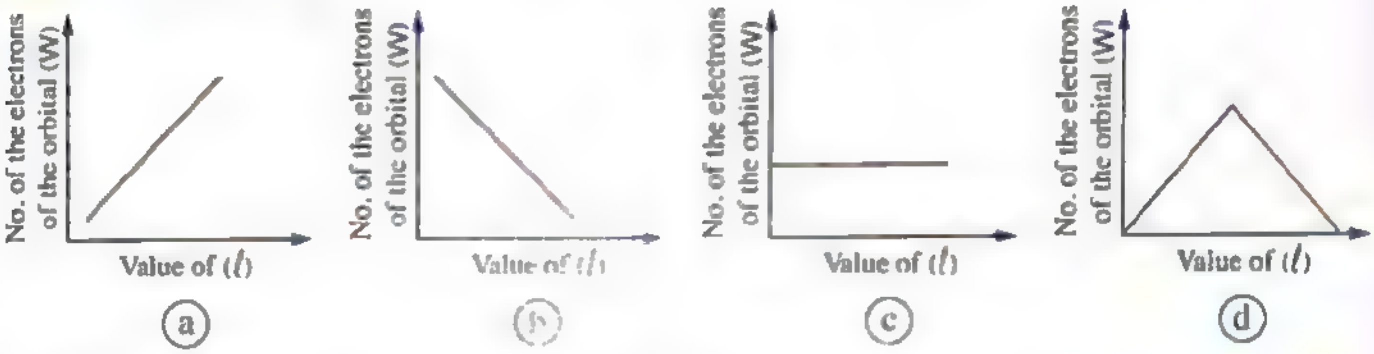
13 **The five electrons present in the sublevel $3d^5$ are similar in all the following, except the ....**

ⓐ principal quantum number.
ⓑ subsidiary quantum number.
ⓒ magnetic quantum number.
ⓓ spin quantum number.

14 Which of the following graphical figures represents the relation between (ℓ) value and the number of orbitals in the sublevel ?

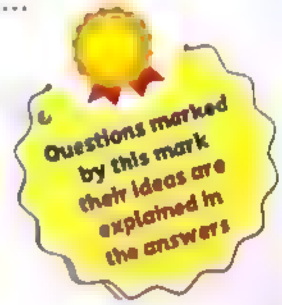


15 Which of the following graphical figures represents the relation between the number of the electrons which fill the orbital (W) in a certain sublevel and the value of (ℓ) of this sublevel ?



16 The energy of the orbital ($3p_z$) is similar to that of the orbital ....

(a) $4p_y$
(b) $3p_x$
(c) $3s$
(d) $2p_z$

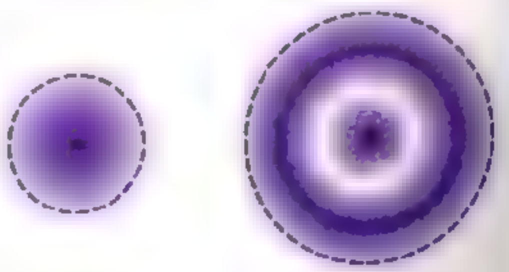


17 The two orbitals ($2s$, $2p_x$) can be similar in ....

(a) the energy.
(b) the shape.
(c) the number of electrons in each of them.
(d) the spatial orientation.

18 The two opposite figures represent two different sublevels.

What is the difference between them ?



(a) Subsidiary quantum number.
(b) Distribution of electron density.
(c) Principal quantum number.
(d) Number of orbitals.

19 Which of the following becomes saturated with the highest number of electrons ?

(a) One of $4f$ orbitals.
(b) $3d$ sublevel.
(c) Principal level (n = 2).
(d) One of $3d$ orbitals.

Questions marked by this mark their ideas are explained in the answers

20 The electrons of *5d* sublevel in one of the atoms cannot have the magnetic quantum number ....

ⓐ +1 ⓑ −1

ⓒ +2 ⓓ +3

21 The electron which has the magnetic quantum number (−3) may have the principal quantum number ....

ⓐ 1 ⓑ 2

ⓒ 3 ⓓ 4

22 Number of orbitals of the sublevel which has the values ($n = 3$), ($l = 2$) is ....

ⓐ 2 ⓑ 3

ⓒ 5 ⓓ 7

23 The electron which has the four quantum numbers :

($n = 4$, $l = 3$, $m_l = +2$, $m_s = +\frac{1}{2}$) is found in the sublevel ....

ⓐ *3d* ⓑ *4f*

ⓒ *5p* ⓓ *6s*

24 Electron (X) has the following quantum numbers : ($n = 3$, $l = 2$, $m_l = -1$, $m_s = -\frac{1}{2}$). What are the quantum numbers of the electron (Y) which have the same energy of the electron (X), but it differs from the electron (X) in the spinning motion ?

ⓐ $n = 3$, $l = 2$, $m_l = -1$, $m_s = +\frac{1}{2}$ ⓑ $n = 3$, $l = 1$, $m_l = -1$, $m_s = -\frac{1}{2}$

ⓒ $n = 3$, $l = 2$, $m_l = 0$, $m_s = -\frac{1}{2}$ ⓓ $n = 2$, $l = 1$, $m_l = 0$, $m_s = +\frac{1}{2}$

25 Which of the following quantum numbers include a mistake ?

ⓐ $n = 2$, $l = 1$, $m_l = +1$ ⓑ $n = 4$, $l = 2$, $m_l = +1$

ⓒ $n = 3$, $l = 3$, $m_l = -2$ ⓓ $n = 3$, $l = 0$, $m_l = 0$

26 Which of the following quantum numbers do not include a mistake ?

ⓐ $n = 2$, $l = 2$, $m_l = +1$ ⓑ $n = 2$, $l = -1$, $m_l = 0$

ⓒ $n = 3$, $l = 2$, $m_l = +3$ ⓓ $n = 4$, $l = 3$, $m_l = -2$

27 Which of the following quantum numbers do not include a mistake ?

ⓐ $n = 5$, $l = 3$, $m_l = 3$ ⓑ $n = 3$, $l = 1$, $m_l = -2$

ⓒ $n = 4$, $l = 0$, $m_l = +1$ ⓓ $n = 3$, $l = 2$, $m_l = -3$

28 Which of the following quantum numbers include a mistake ?

ⓐ $n = 6$, $l = 3$, $m_l = +2$ ⓑ $n = 3$, $l = 2$, $m_l = 0$

ⓒ $n = 4$, $l = 0$, $m_l = -3$ ⓓ $n = 3$, $l = 1$, $m_l = -1$

Essay questions

29 **Determine each of the following :**

(1) The possible (l) values of the electrons in the principal energy level ($n = 4$).

(2) The possible (m_l) values of the electrons in the sublevel ($l = 3$).

30 Show which is higher, **with illustrating the reason,** the maximum number of electrons in the principal level ($n = 2$) **or** the maximum number of electrons in the sublevel *(4d)*.

31 **Estimate** the number of the orbitals which can be occupied with electrons in the principal level ($n = 2$).

32 **Estimate** the number of the orbitals which are present in the sublevel *(f)* in the principal level ($n = 3$).

33 **Suggest** the value of the subsidiary quantum number of the orbital of *4s* sublevel.

34 **The opposite diagram represents** the energy sublevels of the principal energy level ($n = 4$). **Complete the blank cells** with the suitable magnetic quantum numbers (m_l).

Sublevel *f*							
Sublevel *d*							
Sublevel *p*							
Sublevel *s*							

35 **Calculate the maximum number of electrons that can be found in an atom and have the following quantum numbers :**

(1) $n = 3$ (2) $n = 2$, $l = 0$

36 **Choose which of the following energy sublevels cannot be found in the elements known so far:**

$\boxed{1s}$, $\boxed{1p}$, $\boxed{7d}$, $\boxed{9s}$, $\boxed{3f}$, $\boxed{4f}$, $\boxed{2d}$

37 **Suggest the reason of invalidity of the following quantum numbers combinations :**

(1) $n = 3$, $l = 3$, $m_l = +2$

(2) $n = 2$, $l = 1$, $m_l = -2$

(3) $n = 1$, $l = 0$, $m_l = +\frac{1}{2}$, $m_s = +\frac{1}{2}$

Chapter 1

Lesson Four

From Principles of distributing electrons

Until The end of the chapter

Principles of distributing electrons

There are some important rules, which must be considered in distributing electrons in the atom. These rules are :

1. **Pauli's exclusion principle.**
2. **Aufbau (building-up) principle.**
3. **Hund's rule.**

> There is another method for ... the electrons in the element according to the ... noble gas that precedes it in the periodic table, this will be discussed in ...

1 Pauli's exclusion principle

Pauli's exclusion principle :

States that it is impossible for two electrons in the same atom to have the same four quantum numbers.

W. Pauli

Application

The opposite table shows the two electrons of the (3s) sublevel which are similar in the values of the quantum numbers (n, ℓ, m_ℓ), but they are different in the two values of the spin quantum number (m_s).

The four quantum no.	n	ℓ	m_ℓ	m_s
The first electron	3	0	0	$+\frac{1}{2}$
The second electron	3	0	0	$-\frac{1}{2}$

Worked Example

Write the possible values of the four quantum numbers for each of the following :

(a) An electron in $2p$

(b) The first electron in $4d$

(c) The second electron in $1s$

Answer :

The quantum numbers		n	ℓ	$m_\ell = -\ell, .., 0, .., +\ell$	$m_s = \pm\frac{1}{2}$
The possible values of quantum numbers	(a)	2	1	−1 or 0 or +1	$+\frac{1}{2}$ or $-\frac{1}{2}$
	(b)	4	2	−2	$+\frac{1}{2}$
	(c)	1	0	0	$-\frac{1}{2}$

Test Yourself

In helium atom $_2He$, ...

ⓐ the values of the spin quantum [illegible] lar.

ⓑ $m_\ell = 1$

ⓒ the values of the spin quantum [illegible] rent.

ⓓ $m_\ell = -1$

Answer : The correct choice is ......

2 Aufbau (building-up) principle

Aufbau (building-up) principle :

States that the electrons occupy the sublevels in the order of increasing their energy, the lowest energy sublevels are filled first.

* **Arrangement of sublevels according to their energy depends on :**

- **Sum of $(n + \ell)$.**

Ex. Energy of $4s$ sublevel is lower than that of $3d$ sublevel, because the sum of $(n + \ell)$ of $4s$ sublevel is less than that of $3d$ sublevel.

- **Order of the principal energy level.**

"In case that the sum of $(n + \ell)$ value is the same for the two sublevels".

Sequence of filling energy sublevels

Sublevels	Sum of $(n + \ell)$
$3p$	$3 + 1 = 4$
$4s$	$4 + 0 = 4$
$3d$	$3 + 2 = 5$

Ex. Energy of *3p* sublevel is lower than that of *4s* sublevel, because (n) value of *3p* sublevel is lower than that of *4s* sublevel.

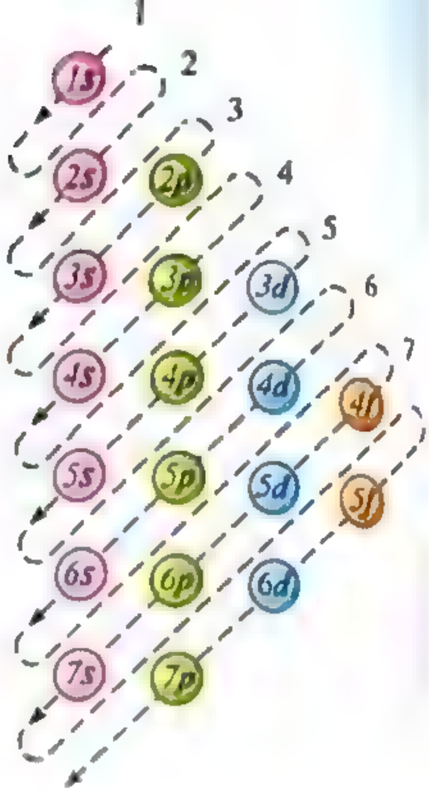
- **The sequence of energy sublevels is arranged ascendingly according to their energy following the order :**

1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d
< 5p < 6s < 4f < 5d < 6p < 7s < 5f < 6d < 7p

- **Filling the energy sublevels :**

$s \xrightarrow{\text{up to}}$ 2 electrons $p \xrightarrow{\text{up to}}$ 6 electrons

$d \xrightarrow{\text{up to}}$ 10 electrons $f \xrightarrow{\text{up to}}$ 14 electrons



A simplified method of filling energy sublevels by following the direction of the arrows

"Numbers 1 : 8 represent the sum of (n + ℓ) of each sublevel"

Test Yourself

What is the number of the orbitals whose (n + ℓ) is less than 5 ?

ⓐ 4
ⓑ 8
ⓒ 9
ⓓ 10

Answer : The correct choice is ....

Worked Example

The opposite table shows the quantum numbers of three electrons (X), (Y) and (Z) in the same atom. Which of the following statements is correct ?

Quantum numbers	(n)	(ℓ)	(m_ℓ)	(m_s)
Electron (X)	4	3	0	$+\frac{1}{2}$
Electron (Y)	6	0	0	$+\frac{1}{2}$
Electron (Z)	5	2	-1	$-\frac{1}{2}$

ⓐ The energy of electron (Y) is higher than that of electron (X).
ⓑ The energy of electron (X) equals that of electron (Z).
ⓒ The energy of electron (Z) is higher than that of electron (Y).
ⓓ The energy of electron (Y) is higher than that ...

wering :

of the electron increases with increasing the value of ($n + l$) and ...

ectron	(X)	(Y)	(Z)
l) value	$4 + 3 = 7$	$6 + 0 = 6$	$5 + 2 = 7$

y of electron (Y) is lower than those of both (X) and (Z)

es (a) and (d) are excluded.

alue of electron (Z) is higher than that of electron (X)

y of electron (Z) is higher than that of electron (X).

e (b) is excluded.

The correct choice is (c)

---

nic configuration of an energy sublevel can b...

Number ...
in the orbitals ...

Principal energy level (n) — $2p^6$

Energy sublevel

ts whose valence electrons are present in sublevels ...

$2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^1$

the chemical reactions to lose the electrons of the lower energy ...
rther from the nucleus) first, then those of the higher energy ...
loser to the nucleus).

d Example

electronic configuration for the following elements, according to
ng-up principle :

Answer :

(1)	${}_{11}Na : 1s^2, 2s^2, 2p^6, 3s^1$
(2)	${}_{20}Ca : 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2$
(3)	${}_{32}Ge : 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^2$

Note

It is clear in the electronic configuration of manganese element ${}_{25}Mn$ that :

$${}_{25}Mn : 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^5$$

- The farthest electron from the nucleus occupies the sublevel $4s$
- The last electron in the atom occupies the sublevel $3d$

Worked Example

The electronic configuration of zinc atom ${}_{30}Zn$ is represented as follows :

$${}_{30}Zn : 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}$$

Conclude the quantum numbers of :

(1) The last electron with the highest energy in the atom of this element.

(2) The farthest electron from the nucleus of the atom of this element.

Answer :

(1) $n = 3, \ell = 2, m_\ell = +2, m_s = -\frac{1}{2}$ $\quad 3d^{10}$ $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}$

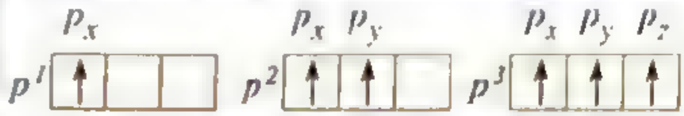
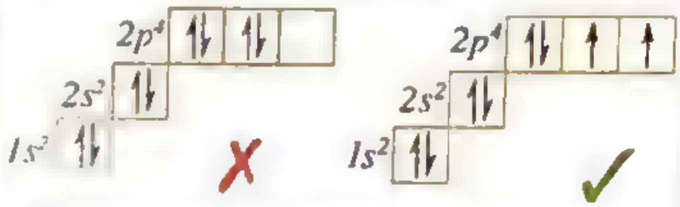
(2) $n = 4, \ell = 0, m_\ell = 0, m_s = -\frac{1}{2}$ $\quad 4s^2$ $\boxed{\uparrow\downarrow}$

3 Hund's rule

Hund's rule :

States that no electron pairing takes place in a given sublevel until each orbital contains one electron.

• Rules of filling the energy sublevels with electrons, according to Hund's rule :

Rules	Applications
The orbitals of the same sublevel are equal in their energy	*The three 2p orbitals are equal in energy* — *The five 3d orbitals are equal in energy*
The orbitals of the same sublevel are filled successively by the unpaired electrons firstly, the spinning of single electrons is in the same direction	*The successive filling of p orbitals with unpaired electrons first*
Electron pairing takes place in the orbitals of the same sublevel after occupying all orbitals by the unpaired electrons first, and these paired electrons have opposite spin directions (being in a spin-paired state) "According to Pauli's exclusion principle"	*The electronic configuration of oxygen atom $_8O$*
The electron prefers to be paired with another electron in one orbital of the same sublevel rather than being transferred to a higher energy sublevel	*The electronic configuration of beryllium atom $_4Be$ «According to Hund's rule»*

Notes

* The spinning of single (unpaired) electrons in the orbitals in same sublevel is in the same direction.

  Because this state gives the atom maximum stability.

* The electron prefers to occupy a separate empty orbital in the same sublevel rather than pairing with another one in the same orbital.

  Because when two electrons are paired in one orbital, (in spite of their opposite spins), there must be a repulsive force that decreases the stability of the atom (increasing its energy).

* The electron prefers pairing with another one in an orbital in the same sublevel rather than transferring to the higher energy sublevel.

  Because the required energy to overcome the repulsive force between the two paired electrons is less than that required for transferring to a higher energy sublevel.

Application

The electronic configuration of some elements according to building-up principle and Hund's rule :

Element	Atomic number	Electronic configuration according to building-up principle	Electronic configuration according to Hund's rule
Hydrogen $_1H$	1	$1s^1$	$1s^1$ $\boxed{\uparrow}$
Helium $_2He$	2	$1s^2$	$1s^2$ $\boxed{\uparrow\downarrow}$
Lithium $_3Li$	3	$1s^2, 2s^1$	$2s^1$ $\boxed{\uparrow}$
Boron $_5B$	5	$1s^2, 2s^2, 2p^1$	$2p^1$ $\boxed{\uparrow}\boxed{}\boxed{}$ $2s^2$ $1s^2$ $\boxed{\uparrow\downarrow}$ $1s^2, 2s^2, 2p_x^1$
Carbon $_6C$	6	$1s^2, 2s^2, 2p^2$	$2p^2$ $\boxed{\uparrow}\boxed{\uparrow}\boxed{}$ $2s^2$ $\boxed{\uparrow\downarrow}$ $1s^2$ $\boxed{\uparrow\downarrow}$ $1s^2, 2s^2, 2p_x^1, 2p_y^1$
Nitrogen $_7N$	7	$1s^2, 2s^2, 2p^3$	$2p^3$ $\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$ $2s^2$ $\boxed{\uparrow\downarrow}$ $1s^2$ $\boxed{\uparrow\downarrow}$ $1s^2, 2s^2, 2p_x^1, 2p_y^1, 2p_z^1$
Fluorine $_9F$	9	$1s^2, 2s^2, 2p^5$	$2p^5$ $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow}$ $2s^2$ $\boxed{\uparrow\downarrow}$ $1s^2$ $\boxed{\uparrow\downarrow}$ $1s^2, 2s^2, 2p_x^2, 2p_y^2, 2p_z^1$
Neon $_{10}Ne$	10	$1s^2, 2s^2, 2p^6$	$2p^6$ $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}$ $2s^2$ $\boxed{\uparrow\downarrow}$ $1s^2$ $\boxed{\uparrow\downarrow}$ $1s^2, 2s^2, 2p_x^2, 2p_y^2, 2p_z^2$

Application

Quantum numbers of electrons of aluminum atom $_{13}Al$:

$_{13}Al : 1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^1$

Electron	1	2	3	4	5	6	7	8	9	10	11	12	13
n	1	1	2	2	2	2	2	2	2	2	3	3	3
ℓ	0	0	0	0	1	1	1	1	1	1	0	0	1
m_ℓ	0	0	0	0	-1	0	$+1$	-1	0	$+1$	0	0	-1
m_s	$+\frac{1}{2}$	$-\frac{1}{2}$	$+\frac{1}{2}$	$-\frac{1}{2}$	$+\frac{1}{2}$	$+\frac{1}{2}$	$+\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	$+\frac{1}{2}$	$-\frac{1}{2}$	$+\frac{1}{2}$

Worked Examples

1 Predict the possible quantum numbers of the valence electrons of vanadium element $_{23}V$

Answer :

- Electronic configuration of the atom of $_{23}V$ is : $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2 , 3d^3$
- The possible quantum numbers are :

1. $n = 4 , \ell = 0 , m_\ell = 0 , m_s = +\frac{1}{2}$
2. $n = 4 , \ell = 0 , m_\ell = 0 , m_s = -\frac{1}{2}$
3. $n = 3 , \ell = 2 , m_\ell = -2 , m_s = +\frac{1}{2}$
4. $n = 3 , \ell = 2 , m_\ell = -1 , m_s = +\frac{1}{2}$
5. $n = 3 , \ell = 2 , m_\ell = 0 , m_s = +\frac{1}{2}$

---

2 Three elements (X) , (Y) and (Z) :

- Element (X) : Its principal energy level ($n = 3$) contains 3 electrons.
- Element (Y) : Its last sublevel is $3s$ which is half filled with electrons.
- Element (Z) : Its electronic configuration is $1s^2 , 2s^2 , 2p^3$

Which of the following are the atomic numbers of (X) , (Y) and (Z) ?

Choices	(X)	(Y)	(Z)
a	11	7	13
b	11	13	7
c	13	11	7
d	13	7	11

Idea of answering :

∵ The electronic configuration of element (X) is : $1s^2, 2s^2, 2p^6, 3s^2, 3p^1$

∴ The atomic number of element (X) = 13

∴ The choices (a) and (b) are excluded.

∵ The electronic configuration of element (Y) is : $1s^2, 2s^2, 2p^6, 3s^1$

∴ The atomic number of element (Y) = 11

∴ The choice (d) is excluded.

* The atomic number of element (Z) is 7

Answer : The correct choice is (c)

---

3 **An element (X) whose electrons are distributed in four pri... energy levels, and its last energy level contains 6 electrons :**

(1) Write the full electronic configuration of the ion (X^{2-}).

(2) What is the number of the unpaired electrons in the last sublevel in the atom of this element ?

(3) What are the quantum numbers of the last electron in the atom of this element ?

Answer :

(1) The full electronic configuration of the element atom (X) :

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^4$

∴ The full electronic configuration of the ion (X^{2-}) :

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^6$

(2) 2 unpaired electrons.

(3) $4p^4$ $\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow}$ $n = 4, \ell = 1, m_\ell = -1, m_s = -\frac{1}{2}$

Ready
Preliminary questions to remember the principal concepts in the lesson

Answer them yourself

Choose the correct answer for each of the following sentences :

(1) Which of the following sublevels has the least energy ?

a. ns b. $(n-1)p$

c. $(n-2)d$ d. $(n-3)p$

(2) The two electrons of $3s$ subl[illegible]

a. principal quantum number. b. [illegible] quantum number.

c. magnetic quantum number. d. spin quantum number.

(3) $(n+\ell)$ represents the energy of the

a. sublevel. b. orbital.

c. principal level. d. electron cloud.

(4) When the $3d$ sublevel is completely filled with electrons, the new electron occupies the ....

a. $4s$ sublevel. b. $4p$ sublevel.

c. $4d$ sublevel. d. $4f$ sublevel.

(5) If the energy sublevel d in an atom contains $8e^-$, so the number of its half filled orbitals is ....

a. 1 b. 2

c. 4 d. 5

(6) What is the number of completely filled orbitals in carbon atom $_6C$ in its ground state ?

a. 1 b. 2

c. 3 d. 5

(7) The total number of the half filled orbitals in $_9F$ atom in its ground state is ....

a. 1

b. 2

c. 3

d. 5

(8) According to Hund's rule, the electron configuration of nitrogen element ($_7N$) is ....

a. $1s^2$, $2s^2$, $2p^3$

b. 2 , 5

c. $1s^2$, $2s^2$, $2p_x^1$, $2p_y^1$, $2p_z^1$

d. $1s^2$, $2s^1$, $2p^4$

(9) The presence of 3 unpaired electrons in phosphorus atom $_{15}P$ in its ground state can be explained by ....

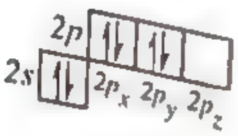
a. Pauli's exclusion principle.

b. Hund's rule.

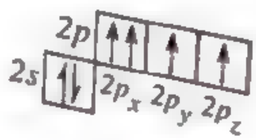
c. the uncertainty principle.

d. Aufbau principle.

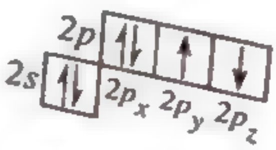
(10) According to Hund's rule the electronic configuration of the last energy level of $_8O$ is ....



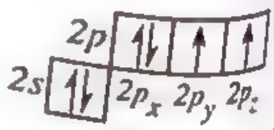
a.



b.



c.



d.

Multiple choice questions

Pauli's exclusion principle

1 **Which of the following statements is correct ?**

ⓐ It is possible sometimes to determine the position and the speed of the electron together precisely at the same time.

ⓑ The sizes of the orbitals of the same atom are similar.

ⓒ The probability of the presence of the electron in the spaces between the energy increases.

ⓓ The two electrons of helium do not have the same four quantum numbers.

2 **If two electrons have [illegible] quantum numbers, it means that these two electrons are found in**

ⓐ the same principal level. ⓑ two different elements atoms.

ⓒ the same orbital. ⓓ the same sublevel.

3 **The two electrons in the same atom which have the same ℓ , m_s values are located in the same ....**

ⓐ sublevel but in different orbitals.

ⓑ principal level but in two different sublevels.

ⓒ orbital.

ⓓ principal level but in different orbitals.

Questions marked by this mark their ideas are explained in the answers

4 **The two electrons, in the same sublevel, which have the same m_s value must differ in the value(s) of ....**

ⓐ n only. ⓑ ℓ only.

ⓒ m_ℓ only. ⓓ ℓ and m_ℓ

5 **The values of the spin quantum number of the electrons of the orbitals of the same sublevel differ when the number of its electrons ....**

ⓐ equals half the number of the orbitals. ⓑ is higher than the number of the orbitals.

ⓒ is lower than the number of the orbitals. ⓓ equals the number of the orbitals.

Aufbau principle

6 According to building-up principle, ...

ⓐ it is impossible to determine both the position and the speed of the nuclear partic... together precisely.

ⓑ the electron occupies the orbital with the lower energy first.

ⓒ the orbital contains mostly 2 electrons.

ⓓ the electrons occupy the equal energy orbitals singly first before being paired.

7 Which is easier, losing an electron from *3d* or from *4s* ?

ⓐ *4s* is more easy as it is closer to the nucleus than *3d*

ⓑ *4s* is less easy as it is closer to the nucleus than *3d*

ⓒ *4s* is more easy as it is farther from the nucleus than *3d*

ⓓ *4s* is less easy as it is farther from the nucleus than *3d*

8 What is the number of the electrons which have magnetic quantum number ($m_l = 0$) in cobalt (II) ion $_{27}Co^{2+}$?

ⓐ $7e^-$ ⓑ $8e^-$ ⓒ $10e^-$ ⓓ $11e^-$

9 The total number of the orbitals which are filled with electrons in the two energy levels (M + L) of the atom of argon $_{18}Ar$ is ....

ⓐ 4 ⓑ 8 ⓒ 9 ⓓ 13

10 Which of the following represents the possible quantum numbers of the last electron in nitrogen atom ?

ⓐ $n = 2$, $l = 1$, $m_l = +1$, $m_s = +\frac{1}{2}$

ⓑ $n = 2$, $l = 1$, $m_l = +1$, $m_s = -\frac{1}{2}$

ⓒ $n = 2$, $l = 1$, $m_l = -1$, $m_s = +\frac{1}{2}$

ⓓ $n = 2$, $l = 1$, $m_l = -1$, $m_s = -\frac{1}{2}$

11 Which of the following are the possible quantum numbers of the last electron which has the highest energy in vanadium $_{23}V$ atom ?

ⓐ $n = 3$, $l = 2$, $m_l = 0$, $m_s = +\frac{1}{2}$

ⓑ $n = 3$, $l = 2$, $m_l = 0$, $m_s = -\frac{1}{2}$

ⓒ $n = 4$, $l = 0$, $m_l = 0$, $m_s = +\frac{1}{2}$

ⓓ $n = 4$, $l = 0$, $m_l = +1$, $m_s = -\frac{1}{2}$

12 Which of the following are the quantum numbers of the 19^{th} electron in the atom of chromium $_{24}Cr$?

ⓐ $n = 3$, $l = 0$, $m_l = 0$, $m_s = +\frac{1}{2}$

ⓑ $n = 3$, $l = 2$, $m_l = -2$, $m_s = +\frac{1}{2}$

ⓒ $n = 4$, $l = 0$, $m_l = 0$, $m_s = +\frac{1}{2}$

ⓓ $n = 4$, $l = 1$, $m_l = -1$, $m_s = +\frac{1}{2}$

13 Which of the following combinations of quantum numbers represents the single electron in the atom of gallium element $_{31}Ga$?

Choices	n	l	(m_l)	(m_s)
ⓐ	3	1	+1	$+\frac{1}{2}$
ⓑ	4	[illegible]	0	$\frac{1}{2}$
ⓒ	4	1	1	$+\frac{1}{2}$
ⓓ	4	2	+1	$+\frac{1}{2}$

14 Which of the electrons that have the following quantum numbers has the highest energy ?

ⓐ $n = 3$, $l = 2$, $m_l = +1$, $m_s = +\frac{1}{2}$

ⓑ $n = 4$, $l = 2$, $m_l = -1$, $m_s = +\frac{1}{2}$

ⓒ $n = 4$, $l = 1$, $m_l = 0$, $m_s = -\frac{1}{2}$

ⓓ $n = 5$, $l = 0$, $m_l = 0$, $m_s = +\frac{1}{2}$

15 What is the number of the electrons which have the principal quantum number ($n = 4$) in the atom of potassium element $_{19}K$?

ⓐ $1e^-$
ⓑ $2e^-$
ⓒ $3e^-$
ⓓ $4e^-$

16 What is the number of the electrons which have the same l and m_l values in the atom of the element $_{15}X$?

ⓐ $3e^-$
ⓑ $5e^-$
ⓒ $9e^-$
ⓓ $15e^-$

17 The opposite table represents the number of electrons which are present in the principal energy levels of an atom of an element in its ground state.

Energy level	K	L	M	N
Number of electrons	2	8	8	2

What is the number of the electrons which have a subsidiary quantum number ($\ell = 1$) ?

ⓐ $8e^-$ ⓑ $10e^-$
ⓒ $12e^-$ ⓓ $20e^-$

18 What is the atomic number of the element whose electrons occupy 8 orbitals ?

ⓐ 8 ⓑ 14
ⓒ 15 ⓓ 26

19 Which of the following is the number of the completely filled orbitals in an element? What is the atomic number of this element ?

Choices	Number of the completely filled orbitals	Atomic number
ⓐ	9	25
ⓑ	10	20
ⓒ	12	22
ⓓ	13	24

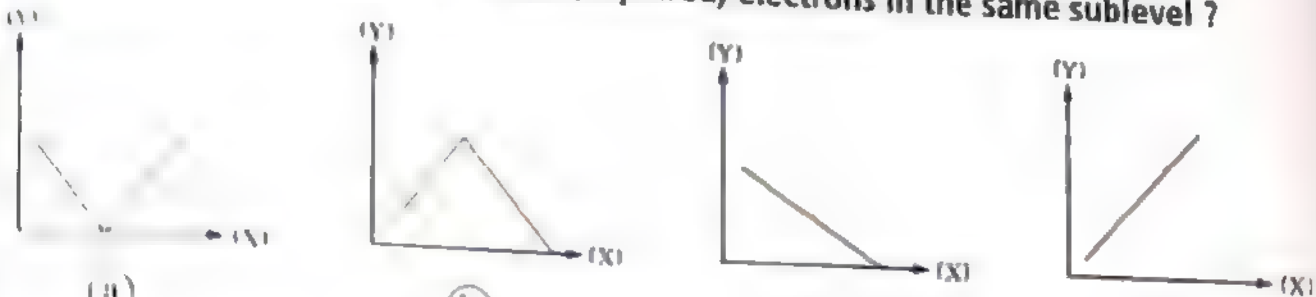
20 The number of the orbitals which are half filled with electrons equals the numerical value of the principal quantum number of the electrons of the last energy sublevel in the atom of the element ....

ⓐ $_{7}N$ ⓑ $_{8}O$
ⓒ $_{9}F$ ⓓ $_{10}Ne$

21 What is the number of electrons of the last principal energy level of the element which contains 15 completely filled and 2 half filled orbitals ?

ⓐ $2e^-$
ⓑ $3e^-$
ⓒ $4e^-$
ⓓ $5e^-$

22 Which of the following graphical figures represents the relation between (X) which represents the number of the electrons of the sublevel *3d* and (Y) which represents the number of the single (unpaired) electrons in the same sublevel ?



(a) (b) (c) (d)

23 What is the number of the electrons which can have the magnetic quantum number –3 in the sublevel $4f^9$?

(a) $1e^-$ (b) $2e^-$

(c) $3e^-$ (d) $4e^-$

24 The last energy sublevel in an element consists of 3 orbitals X, Y and Z containing only one electron, and the value $(n + \ell)$ of this sublevel equals 5.

What is the atomic number of this element ?

(a) 19 (b) 31

(c) 33 (d) 41

25 An element its valence shell contains a number of electrons equals each of :

- Number of the principal levels.
- Number of the sublevels.
- Number of its orbitals.

What is the symbol of this element ?

(a) $_3Li$ (b) $_2He$

(c) $_4Be$ (d) $_7N$

26 In iron element $_{26}Fe$, the number of the half filled orbitals is equal to the value of one of the quantum numbers of the farthest electron from the nucleus.

Which of the following is this quantum number ?

(a) Principal quantum number. (b) Subsidiary quantum number.

(c) Magnetic quantum number. (d) Spin quantum number.

27 What is the number of electrons of the penultimate principal energy level of the element whose atomic number is 28 ?

ⓐ $2e^-$ ⓑ $8e^-$

ⓒ $14e^-$ ⓓ $16e^-$

28 An element (X), the principal quantum number of its farthest electron from the nucleus is (n = 4), if the number of electrons found in the energy level M is dou their number in the level L

What is the atomic number of (X) ?

ⓐ 18 ⓑ 26

ⓒ 28 ⓓ 36

29 What is the electronic configuration of the outermost ([illegible]) energy level of a stabl atom that has 7 valence electrons ?

ⓐ $3s^1, 3p^6$ ⓑ $3s^1, 3p^4, 3d^2$

ⓒ $3s^2, 3p^5$ ⓓ $3s^2, 2p^4, 3d^1$

30 The last sublevel in X^{3+} ion is $2p^6$

What is the number of the half filled orbitals in the atom of X ?

ⓐ Zero ⓑ 1

ⓒ 2 ⓓ 3

31 Which of the following represents the sublevels from which the electrons are lost when the atom of the element $_{21}Sc$ is converted to M^{3+} ion ?

ⓐ $3s, 4s$ ⓑ $4s, 3d$

ⓒ $3d, 4p$ ⓓ $4s, 4p$

32 Which of the following represents the electronic configuration of $_{40}Zr^{2+}$ ion according to Aufbau principle ?

ⓐ $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 4p^6, 5s^2, 5p^6, 6s^2, 6p^2$

ⓑ $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2, 4p^6, 4d^2$

ⓒ $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2, 4p^6, 5s^2$

ⓓ $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2, 4p^6, 4f^2$

33 What is the electronic configuration which represents an excited atom ?

ⓐ $_9F : 1s^2 , 2s^2 , 2p^5$ ⓑ $_7N : 1s^2 , 2s^2 , 2p^3$

ⓒ $_2He : 1s^2$ ⓓ $_3Li : 1s^2 , 2p^1$

34 Which of the following represents the electronic configuration of the atom of gallium $_{31}Ga$ in its excited state ?

ⓐ 2, 8, 17, 3 ⓑ 2, 8, 17, 4

ⓒ 2, 8, 18, 3 ⓓ 2, 8, 18, 4

Hund's rule

35 Which of the following represents the spin motion of the electrons of the last energy sublevel in $_{18}Ar$ atom ?

ⓐ $\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$ ⓑ $\boxed{\uparrow\downarrow}\boxed{\uparrow\uparrow}\boxed{\downarrow\uparrow}$

ⓒ $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}$ ⓓ $\boxed{\uparrow\downarrow}\boxed{\downarrow\downarrow}\boxed{\uparrow\downarrow}$

36 Which of the following violates Pauli's principle ?

ⓐ $\boxed{\uparrow\downarrow}\ \boxed{\uparrow\downarrow}\boxed{}\boxed{}$ ⓑ $\boxed{\uparrow\uparrow}\ \boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

ⓒ $\boxed{\uparrow\downarrow}\ \boxed{\uparrow}\boxed{\downarrow}\boxed{\uparrow}$ ⓓ $\boxed{\uparrow}\ \boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

37 According to Hund's rule and Pauli's exclusion principle, the last two electrons in $3d$ sublevel in the atom of the element $_{26}X$ are different in the two quantum numbers ....

ⓐ l and m_l ⓑ n and m_l

ⓒ l and m_s ⓓ m_l and m_s

38 This configuration of fluorine atom $_9F$ in its stable state does not obey ....

$\boxed{\uparrow\downarrow}\ \boxed{\uparrow\downarrow}\ \boxed{\uparrow\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

ⓐ Aufbau principle only.

ⓑ Hund's rule only.

ⓒ exclusion principle only.

ⓓ both Hund's rule and exclusion principle.

Essay questions

39 **Reuse the opposite figure** of the three axes **to draw the shapes of** the sublevels in the principal level (n = 2).

40 **Use your knowledge about the quantum numbers to write** one of the six possibilities of an electron that is found in one of *3p* orbitals.

41 According to Pauli's exclusion principle, no two electrons in the same atom can have the same four quantum numbers.
What are the similarities between the possibilities of the quantum numbers of two electrons found in the orbitals of *2p* sublevel ? **In what may they differ ?**

42 **Verify** Pauli's principle on the two electrons of the last orbital of chloride ion $_{17}Cl$

43 **Illustrate with explanation whether each of Pauli's principle** and **Hund's rule is applied to each of the following cases :**

(1) | ↑↑ | ↑ | ↑ |

(2) | ↑↓ | ↑ | ↓ |

44 **Deduce the atomic number** of the element whose last electron has the quantum numbers

$$(n = 2 \ , \ l = 1 \ , \ m_l = +1 \ , \ m_s = +\frac{1}{2})$$

45 **What is the maximum number** of electrons in an atom in which the last electron with the highest energy has the two quantum numbers :

(1) $n = 3 \ , m_s = +\frac{1}{2}$

(2) $n = 4 \ , m_l = +3$

46 **Predict** the possible quantum numbers of the valence electrons of titanium $_{22}Ti$

47 **An element (X) its electrons are distributed in four principal energy levels, the last level contains 6 electrons :**

(1) Write the full electronic configuration of the ion X^{2-}

(2) What are the quantum numbers of the third electron in the last energy sublevel in the atom of this element ?

Exam model on Chapter 1

Superior	Remarkable	above average	Weak
from 30 to 27 marks	from [illegible] to 21 marks	from 20 to 15 marks	less than 15 marks

Choose the correct answer for the questions 1 : 21 . (21 marks)

1 When a sample of phosphorus–35 isotope whose mass is 1 g is left for 14 days, it is found that the mass of the sample decreased by half.
This observation does not match ....

ⓐ Democritus's idea of the atom only.
ⓑ Boyle's idea of matter only
ⓒ Dalton's atomic m[illegible]
ⓓ Democritus's [illegible] and Dalton's atomic model.

2 The number of [illegible] the sublevel which has the two values ($n = 4$, $\ell = 3$) is ....

ⓐ 2
ⓑ 3
ⓒ 5
ⓓ 7

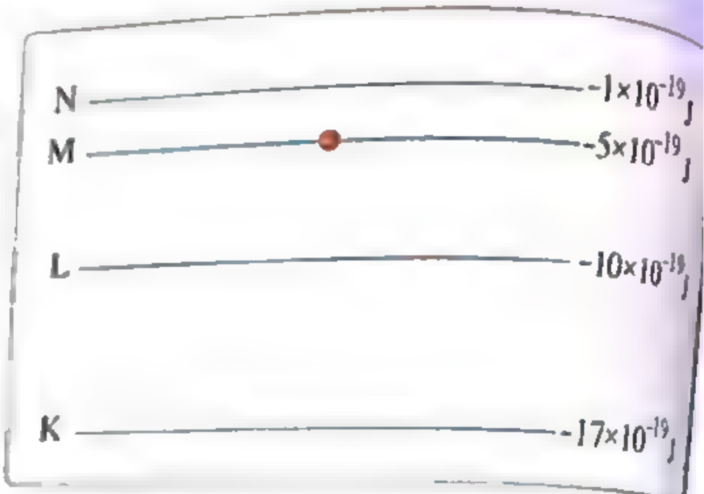
3 What does the opposite figure represent ?

ⓐ The structure of helium atom ${}_2He$
ⓑ The two electrons of p_x are in a spin-paired state.
ⓒ The two electrons of the same orbital carry the same charge.
ⓓ Pauli's exclusion principle.

4 What is the atomic number of the element whose level which has the principal quantum number ($n = 3$) contains 13 electrons ?

ⓐ 17
ⓑ 23
ⓒ 25
ⓓ 43

5 **The opposite figure demonstrates the energy levels of a hypothetical atom, if an electron transfers from the energy level M to K, then it ....**



ⓐ acquires an amount of energy equals 5×10^{-19} J

ⓑ acquires an amount of energy equals 12×10^{-19} J

ⓒ loses an amount of energy equals 5×10^{-19} J

ⓓ loses an amount of energy equals 12×10^{-19} J

6 **What happens to the electron by increasing the distance between its orbital and the nucleus ?**

ⓐ Both its kinetic and potential energies decrease.

ⓑ Its kinetic energy decreases and its potential energy increases.

ⓒ Both its kinetic and potential energies increase.

ⓓ Its kinetic energy increases and its potential energy decreases.

7 **What is the maximum number of electrons that can have the quantum numbers ($n = 3$, $\ell = 1$, $m_\ell = -1$) in the same atom ?**

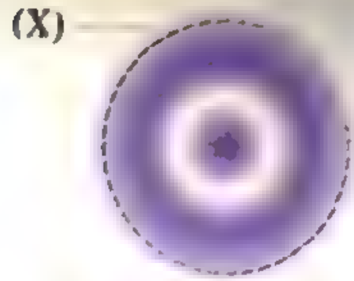
ⓐ $10e^-$ ⓑ $6e^-$

ⓒ $4e^-$ ⓓ $2e^-$

8 **The electrons of the last energy level in neon atom occupy several orbitals which have two different shapes.**
Which of the following represents correctly one of these orbitals ?

Choices	Shape of the orbital	Energy of this orbital compared to the other orbitals
ⓐ		Higher than or equal to them
ⓑ		Higher than or equal to them
ⓒ		Lower than or equal to them
ⓓ		Lower than or equal ...

9 What does (X) represent in the opposite figure ?



ⓐ The electron cloud of $2s$ sublevel.

ⓑ The orbital $2p$

ⓒ The orbital $2s$

ⓓ The second orbit in hydrogen atom.

10 On comparing the energy and the charge of the electrons in the energy level L in Be atom to those of the electrons of the energy level K they are found to have ....

ⓐ lower energy but the same charge.

ⓑ higher energy but the same charge.

ⓒ lower energy but the same (n) value

ⓓ higher energy but the same (n) value.

11 Which of the following electronic configurations violates aufbau principle ?

ⓐ [↑↓] [↑↓] [↑↓][ ][ ]

ⓑ [↑↓] [↑] [ ][ ][ ]

ⓒ [↑] [↑] [↑][↓][↑]

ⓓ [↑↓] [↑↑] [↑][ ][ ]

12 Which of the following sets of quantum numbers expresses the electron of an excited hydrogen atom ?

ⓐ $n = 4$, $\ell = 3$, $m_\ell = -3$

ⓑ $n = 4$, $\ell = 4$, $m_\ell = -2$

ⓒ $n = 5$, $\ell = -1$, $m_\ell = +2$

ⓓ $n = 3$, $\ell = 1$, $m_\ell = -2$

13 What is the maximum number of electrons in an atom which has the two quantum numbers ($n = 2$, $\ell = 1$) ?

ⓐ 2

ⓑ 4

ⓒ 6

ⓓ 10

14 **What is the correct order of the orbitals in titanium atom according to the increase of energy ?**

ⓐ $3s < 3p < 3d < 4s$

ⓑ $3s < 3p < 4s < 3d$

ⓒ $3s < 4s < 3p < 3d$

ⓓ $4s < 3s < 3p < 3d$

15 **Which of the following electronic configurations represents the ground state of an atom that contains 8 electrons ?**

ⓐ 

ⓑ 

ⓒ 

ⓓ 

16 **Among the recently known scientific facts are :**

(1) : The fission of uranium –235 atoms produces atoms of barium –141 and krypton –92

(2) : The difference of the mass of oxygen isotope 16 from that of oxygen isotope 17

(3) : The mass of the atom of argon –36 equals the mass of sulphur isotope 36

What are the facts which are not consistent with Dalton's atomic model ?

ⓐ (1) and (2) only.

ⓑ (2) and (3) only.

ⓒ (1) and (3) only.

ⓓ (1) , (2) and (3).

17 **What is the atomic number of the atom of the element whose orbitals contain 3 unpaired electrons ?**

ⓐ 5

ⓑ 13

ⓒ 15

ⓓ 21

18 Which of the following transfers in hydrogen atom produces the largest quantum of energy ?

ⓐ $(n = 7) \longrightarrow (n = 6)$

ⓑ $(n = 7) \longrightarrow (n = 5)$

ⓒ $(n = 4) \longrightarrow (n = 3)$

ⓓ $(n = 2) \longrightarrow (n = 1)$

19 Which of the following represents the electronic configuration of an excited phosphorus atom ?

ⓐ $1s^2, 2s^2, 2p^6, 3s^2, 3p^3$

ⓑ $1s^2, 2s^2, 2p^6, 3s^2, 3p^1$

ⓒ $1s^2, 2s^2, 2p^6, 3s^2, 3p^2, 4s^1$

ⓓ $1s^2, 2s^2, 2p^6, 3s^2, 3p$ $\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{}$

20 Among the modifications introduced by the modern atomic theory to the older theories is ....

ⓐ it is impossible to determine both the position and speed of the 11^{th} electron in $_{11}Na$ atom precisely at the same time.

ⓑ the electron is negatively charged.

ⓒ most of the atomic volume is an empty space.

ⓓ the spaces between energy levels are forbidden for the electrons.

21 The opposite electronic configuration violates ....

$\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

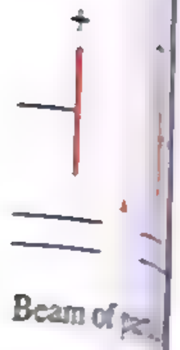
ⓐ Aufbau principle only.

ⓑ Pauli's exclusion principle only.

ⓒ Hund's rule only.

ⓓ Pauli's principle and Hund's rule.

22 The scientists verified the presence of the electrons, protons and neutrons in the atom during the centuries 19 and 20, if a beam of each of them is passed through an electric field (as in the opposite figure) :



(1) In which direction will the deflection be ? Explain.

....

....

....

(2) Which of these particles will be deflected more ? Explain.

....

....

....

23 Complete the following table :

(n)	(l)	(m_l)	The orbital
2	1	−1	$2p_x$
1	0	0	....
4	....	+3	....
....	....	....	$4p_y$
3	2	−2	....

24 The opposite figures represent two attempts to explain the atomic structure :

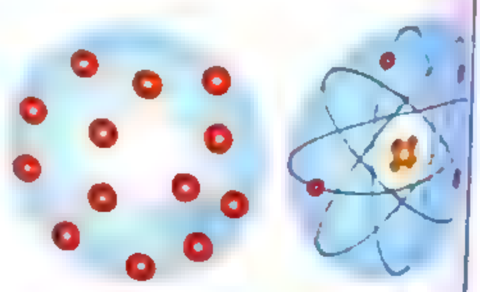
(1) What is the name of the theory which each figure represents ?

(1) : ....

(2) : ....

(2) What is the similarity between these theories ?

....



(1) (2)

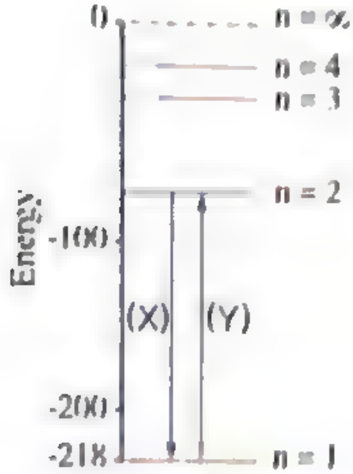
In the opposite figure :

Which of the two processes

(X) and (Y) requires losing energy ?

What is the scientific term

of this amount of energy ?



....

....

1 mark

The two opposite figures represent

the emission of the green light

the red light - with no particular order

as a result of returning an excited

electron to its ground state in

hydrogen atom.

Which of them represents the green light ? Explain.

Figure (1)

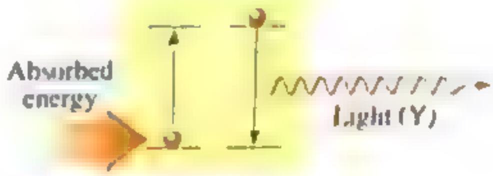


Figure (2)

....

....

....

....

1 mark

27 The opposite figures represent

3 different orbitals in an atom.

complete below figures (2) and (3)

with what is suitable, taking

into consideration the sizes

of the orbitals.

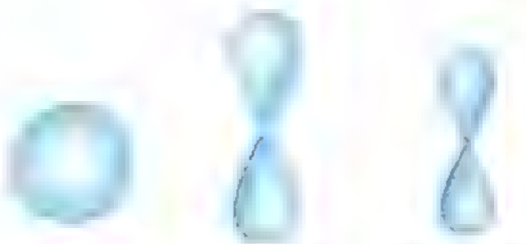


Figure (1)	Figure (2)	Figure (3)
3s	....	....

1 mark

CHAPTER

2

The Periodic Table and Classification of Element

Lesson One

From: The long form (modern) periodic table.

Until: Before trends and periodicity of properties in the periodic

Lesson Two

From: Trends and periodicity of properties in the periodic ta

Until: Before metallic and nonmetallic property.

Lesson Three

From: Metallic and nonmetallic property.

Until: Before the oxidation numbers.

Lesson Four

From: The oxidation n

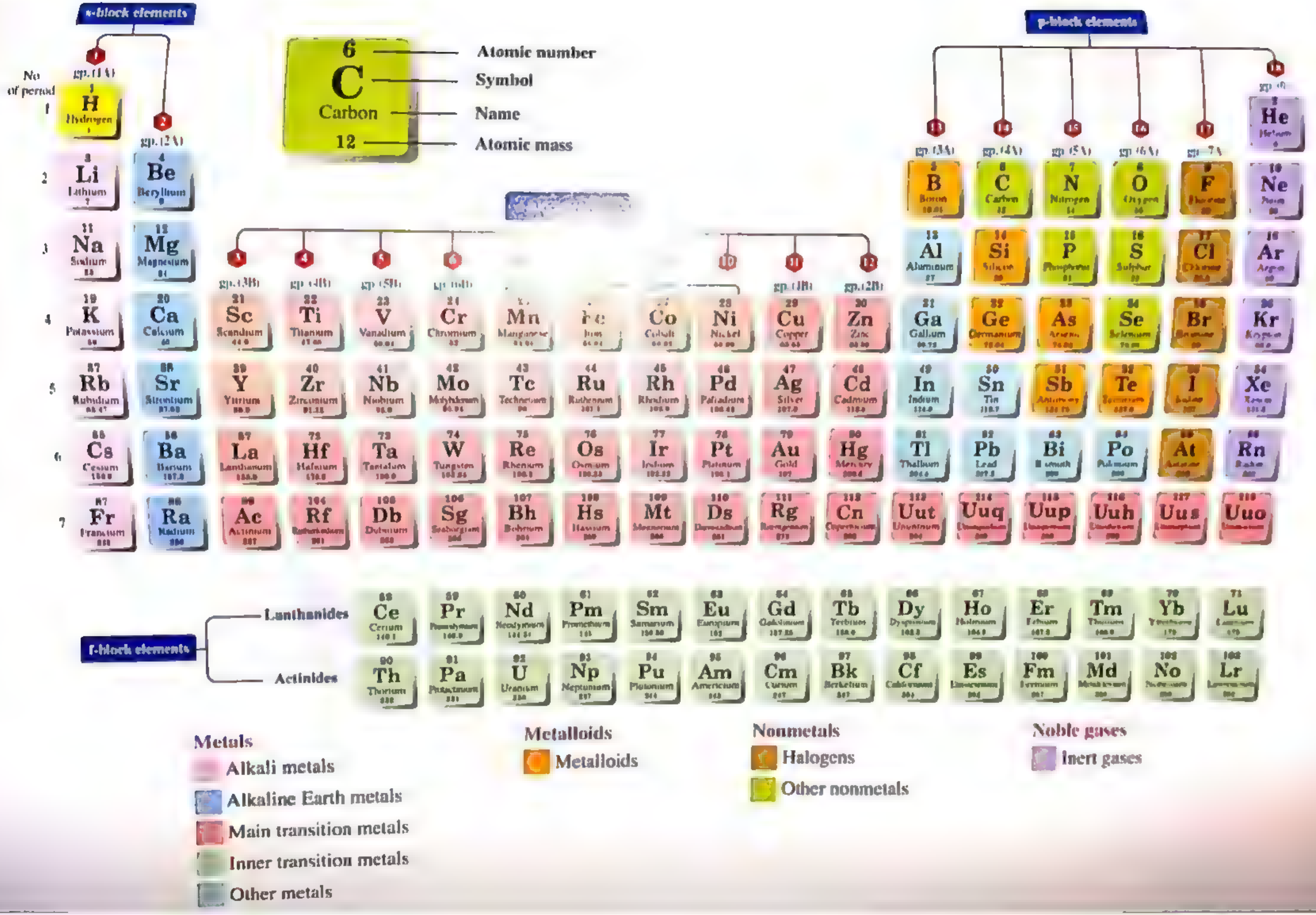
Until: The end of the ch

Exam model on the chapter

General objectives of the chapter

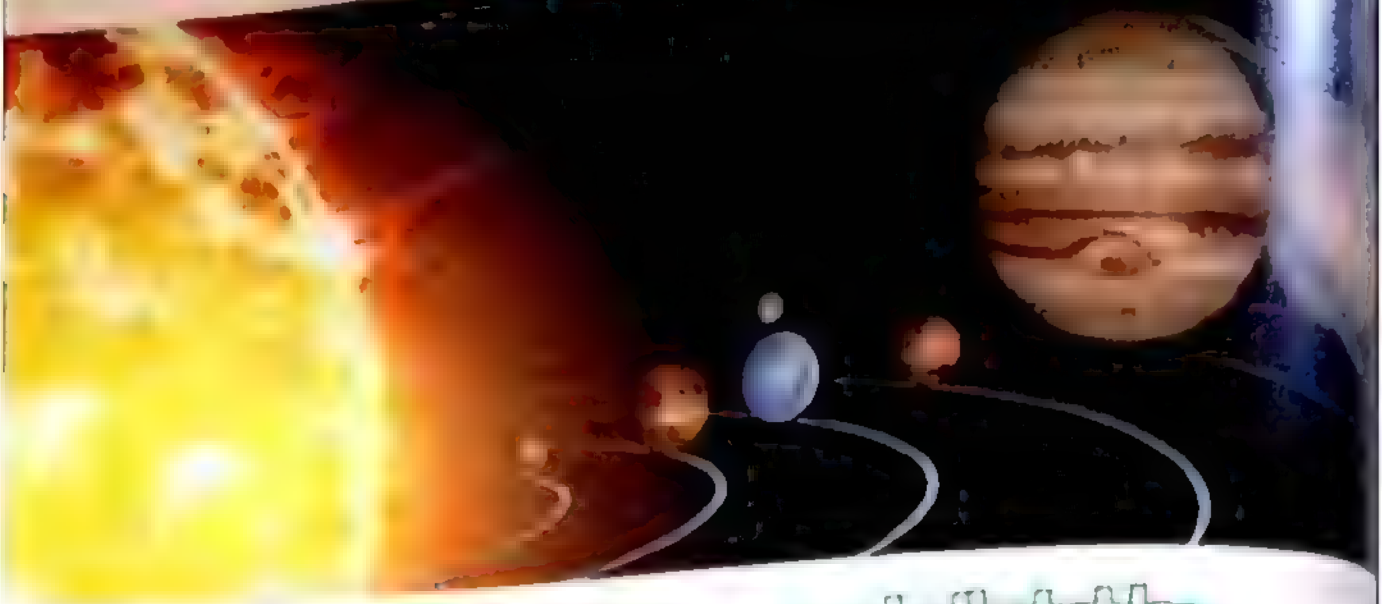
By the end of this unit, the student will be able to :

- Describe the long form periodic table.
- Arrange the energy sublevels according to the building-up principle.
- Identify the type of the element and its properties from its location in the table.
- Calculate the atomic radius by using bond length.
- Explain the factors affecting the atomic radius across the periods and groups.
- Define the location of the four blocks of the table.
- Find the relationship between the electronic configuration of the elements of the same groups.
- Define the atomic radius, ionization energy, electron affinity and electronegativity.
- Compare between the electron affinity and electronegativity.
- Identify the location of metals and nonmetals.
- Find the relationship between atomic radius, ionization energy and electron affinity in metals and nonmetals
- Identify the relationship between the atomic radius and the acidic and basic properties.
- Discuss the ionization of acids and bases as hydroxyl compounds.
- Calculate the oxidation number.
- Explain the oxidation and reduction in different reactions


s-block elements
p-block elements
f-block elements
6
C
Carbon
12
Atomic number
Symbol
Name
Atomic mass
Lanthanides
Actinides
Metals
Alkali metals
Alkaline Earth metals
Main transition metals
Inner transition metals
Other metals
Metalloids
Metalloids
Nonmetals
Halogens
Other nonmetals
Noble gases
Inert gases

Chapter 2

Lesson One



The modern periodic table

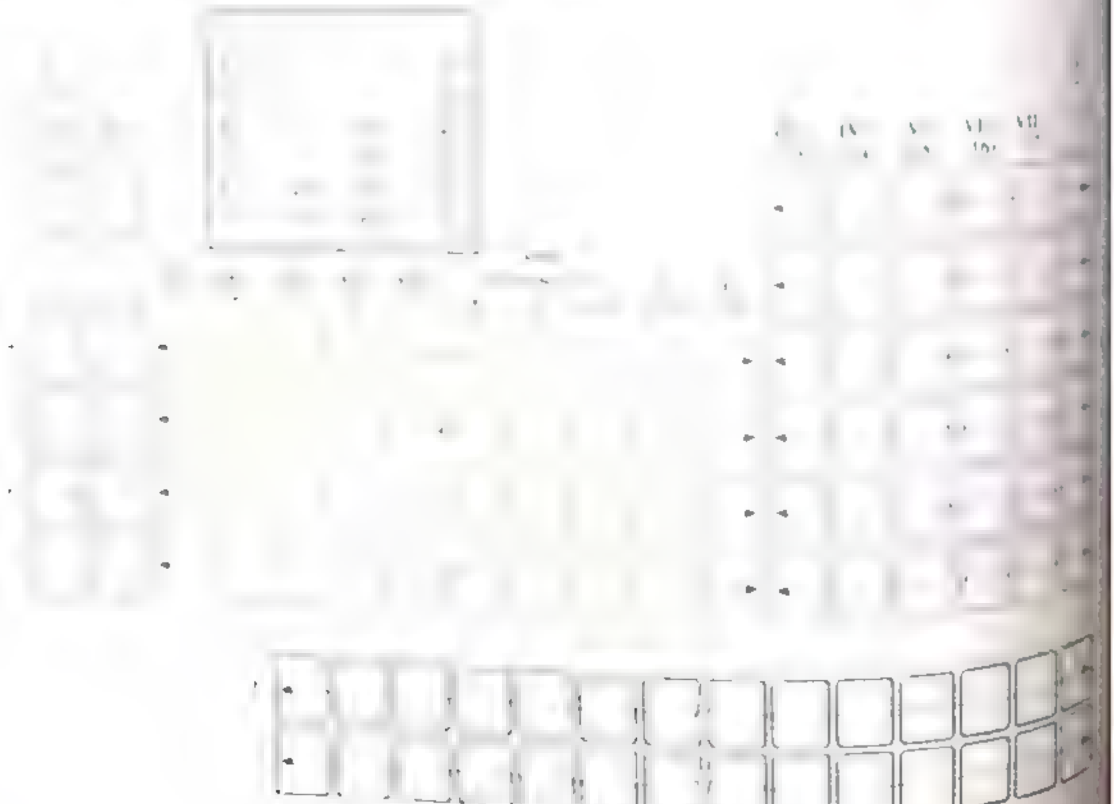
The modern periodic table consists - as shown on the previous page - of :

- 7 periods (horizontal rows).
- 18 groups (vertical columns).

The elements are arranged ascendingly according to:

- Their atomic numbers (number of protons).
- The sequence of filling energy sublevels with electrons according to the Aufbau (building up) principle, where each element has one more [illegible] than the element which precedes it in the same [illegible]

The atom is electrically [illegible] in its elemental state [illegible] number of positive protons [illegible] number of negative electrons [illegible]



The modern periodic table

Each period begins by filling a new principal energy level with one electron, then filling the energy sublevels lying in the same principal energy level successively, until we reach the last element in the period which is a noble gas in which all the levels are completely filled with electrons.

Elements of the same group	Elements of the same period
* Similar in their chemical properties, as they are similar in the electronic configuration of the last level (the valence shell).	* Different in their chemical properties, as they are different in the electronic configuration of the last level (the valence shell).
* Different in the principal quantum number (n) of this last energy level.	* Similar in the principal quantum number (n) of this last energy level.

Test Yourself

The chemical properties are much alike in the two elements ....

ⓐ $_{13}Al$, $_{14}Si$

ⓑ $_{4}Be$, $_{5}B$

ⓒ $_{11}Na$, $_{19}K$

ⓓ $_{15}P$, $_{16}S$

Answer : The correct choice is ....

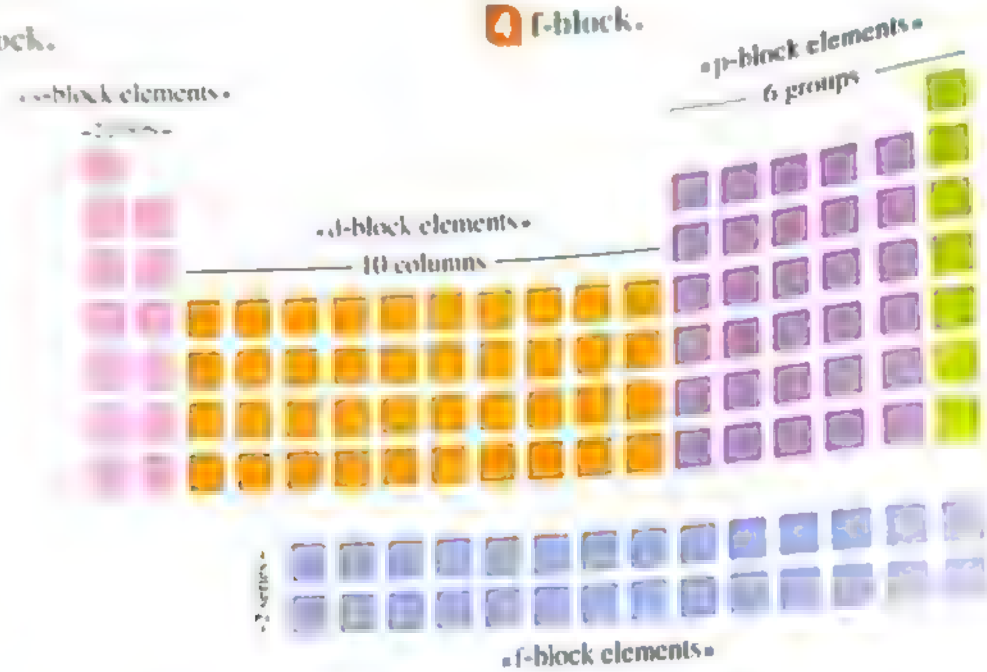
* The modern periodic table consists of 118 elements distributed in seven horizontal periods, as follows :

Period	First	Second	Third	Fourth	Fifth	Sixth	Seventh
Number of elements	2	8	8	18	18	32	32

The elements blocks of the modern periodic table

- The table is divided into four main blocks, these blocks are :

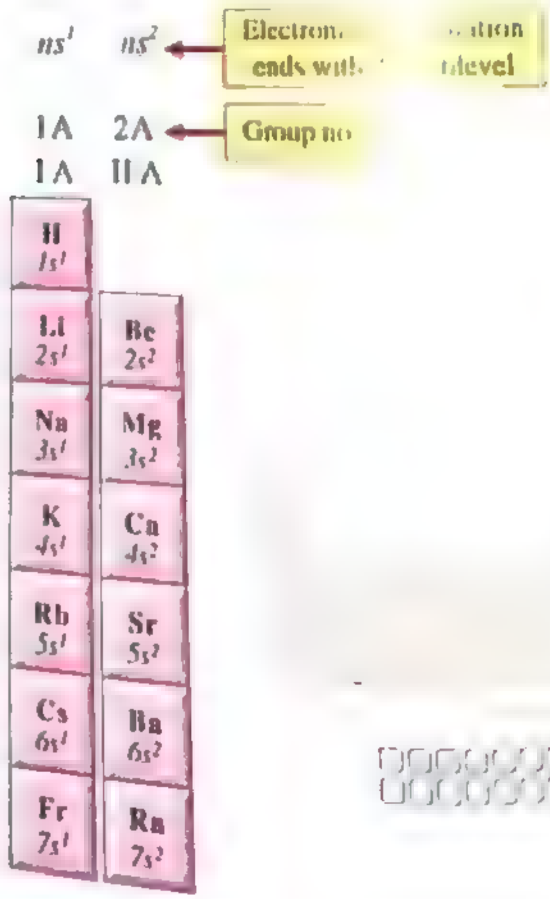
1. s-block.
2. p-block.
3. d-block.
4. f-block.



The blocks of the modern periodic table

1 s-block elements

- They are placed in the left side of the table.
- The s-block contains the elements whose outermost electrons occupy the "s" sublevel «except ^4_2He».
- The s-block consists of two groups of elements, they are :
  - 1A whose electronic configuration ends with ns^1
  - 2A whose electronic configuration ends with ns^2
- Where "n" stands for the number of the outermost energy level as well as the number of the period.

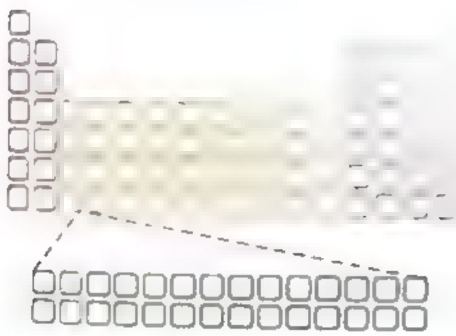


The two groups of s-block

2 p-block elements

- They occupy the right side of the table.
- The p-block includes the elements whose outermost electrons occupy the "p" sublevel and their electronic configurations end with (ns^2, $np^{1:6}$), (except helium $1s^2$).
- The p-block consists of six groups, characterized by the letter "A" except "group zero", as follows :

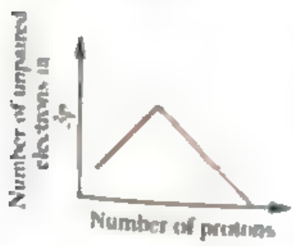
Electronic configuration ends with the sublevel	np^1	np^2	np^3	np^4	np^5	np^6
Group no.	3A	4A	5A	6A	7A	0
	IIIA	IVA	VA	VIA	VIIA	He $1s^2$
	[illegible]	C $2p^2$	N $2p^3$	O $2p^4$	F $2p^5$	Ne $2p^6$
	[illegible]	Si $3p^2$	P $3p^3$	S $3p^4$	Cl $3p^5$	Ar $3p^6$
	Ga $4p^1$	Ge $4p^2$	As $4p^3$	Se $4p^4$	Br $4p^5$	Kr $4p^6$
	In $5p^1$	Sn $5p^2$	Sb $5p^3$	Te $5p^4$	I $5p^5$	Xe $5p^6$
	Tl $6p^1$	Pb $6p^2$	Bi $6p^3$	Po $6p^4$	At $6p^5$	Rn $6p^6$



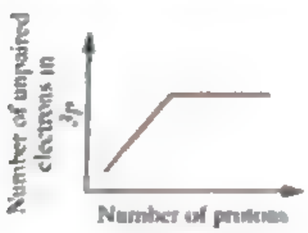
The groups of p-block

Test Yourself

Which of the following graphical figures represents the relation between the number of the unpaired electrons in the orbitals of $3p$ sublevel and the number of the protons in the atoms of elements of the third period in the periodic table ?

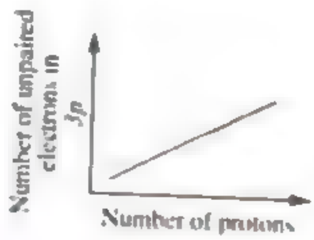


(a)



(b)

(c)



(d)

Answer : The correct choice is ....

3 d-block elements

- They occupy the middle of the table.
- The d-block contains the elements with the outermost electrons occupy the "d" sublevel and their electronic configurations end with $(ns^{1,2}, (n-1)d^{1-10})$.
- The d-block consists of "10" vertical columns representing "8" groups which are characterized by the symbol "B" except (the eighth group (VIII)) which consists of "3" vertical columns.
- The d-block elements are classified according to the number of the outermost energy level and the period number into three series (each contains 10 elements), which are :

Included Information

The electronic configurations of the elements of the second and third transition series are irregularly configured as shown in the table, pages (105, 106)

Electronic configuration of the last d sublevel	$(n-1)d^1$	$(n-1)d^2$	$(n-1)d^3$	$(n-1)d^5$	[illegible]	[illegible]	[illegible]	$(n-1)d^8$	$(n-1)d^{10}$	$(n-1)d^{10}$
Group no.	3B	4B	5B	6B	7B				1B	2B
The first transition series	Sc $3d^1$	Ti $3d^2$	V $3d^3$	Cr $3d^5$	Mn [illegible]	[illegible]	[illegible]	Ni $3d^8$	Cu $3d^{10}$	Zn $3d^{10}$
The second transition series	Y $4d$	Zr $4d$	Nb $4d$	Mo $4d$	Tc $4d$	Ru $4d$	Rh $4d$	Pd $4d$	Ag $4d$	Cd $4d$
The third transition series	La $5d$	Hf $5d$	Ta $5d$	W $5d$	Re $5d$	Os $5d$	Ir $5d$	Pt $5d$	Au $5d$	Hg $5d$

The groups of d-block

1 The first transition series :

- It includes the elements in which the "$3d$" sublevel is filled successively.
- It lies in the fourth period and includes the elements from scandium ($_{21}Sc$) to zinc ($_{30}Zn$)

2 The second transition series :

- It includes the elements in which the "$4d$" sublevel is filled successively.
- It lies in the fifth period and includes the elements from yttrium ($_{39}Y$) to cadmium ($_{48}Cd$)

3 The third transition series :

- It includes the elements in which the "$5d$" sublevel is filled successively.
- It lies in the sixth period and includes the elements from lanthanum ... to mercury ($_{80}Hg$)

Test Yourself

Which quantum numbers represent the orbitals that are filled successively with electrons in the elements $_{21}Sc$ to $_{30}Zn$?

ⓐ $n = 3$, $\ell = 1$ ⓑ $n = 3$, $\ell = 2$ ⓒ $n = 4$, $\ell = 1$ ⓓ $n = 4$, $\ell = 2$

Idea of answering :

∵ The elements from $_{12}Sc$ to $_{30}Zn$ are the elements of the .... transition series which lies in the .... period, in this series the sublevel .... is succesively filled with electrons.

∴ $n =$ .... , $\ell =$ ....

Answer : The correct choice is ....

4 f-block elements

- They are separated down the table, to avoid being too long.
- In this block the "f" sublevel is filled successively.
- The f-block is divided into ... (each contains 14 elements), which are :

> **Included information**
>
> The electronic configurations of the elements of f-block are not regularly configured as shown in the table, page (106).

Lanthanides series	Ce $4f^1$	Pr $4f$	Nd $4f$	Pm $4f$	Sm $4f$	Eu $4f$	Gd $4f$	Tb $4f$	Dy $4f$	Ho $4f$	Er $4f$	Tm $4f$	Yb $4f$	Lu $4f^{14}$
Actinides series	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

The two series of f-block

❶ The lanthanides series:

- It is placed in the sixth period, in which the "$4f$" sublevel is filled successively, it includes 14 elements.
- The elements of this series were named - inaccurately - by rare earths, because they are quite similar in behavior and very difficult to be separated from each other as the outermost energy level for all of them is $6s^2$

However, that name is not accurate, as recently their oxides could be separated by **ionic exchange.**

2 The actinides series :

- It is placed in the seventh period, in which the "5f" sublevel is filled successively, it also includes 14 elements.
- All the elements of this series are radioactive (their nuclei are unstable).

Worked Example

What is the block of elements which includes the largest number of elements in the sixth period in the periodic table ?

(a) s-block.

(b) p-block.

(c) d-block.

(d) f-block.

Idea of answering :

The sixth period includes elements of the blocks s, p, d and f, these blocks are filled successively with electrons as follows :

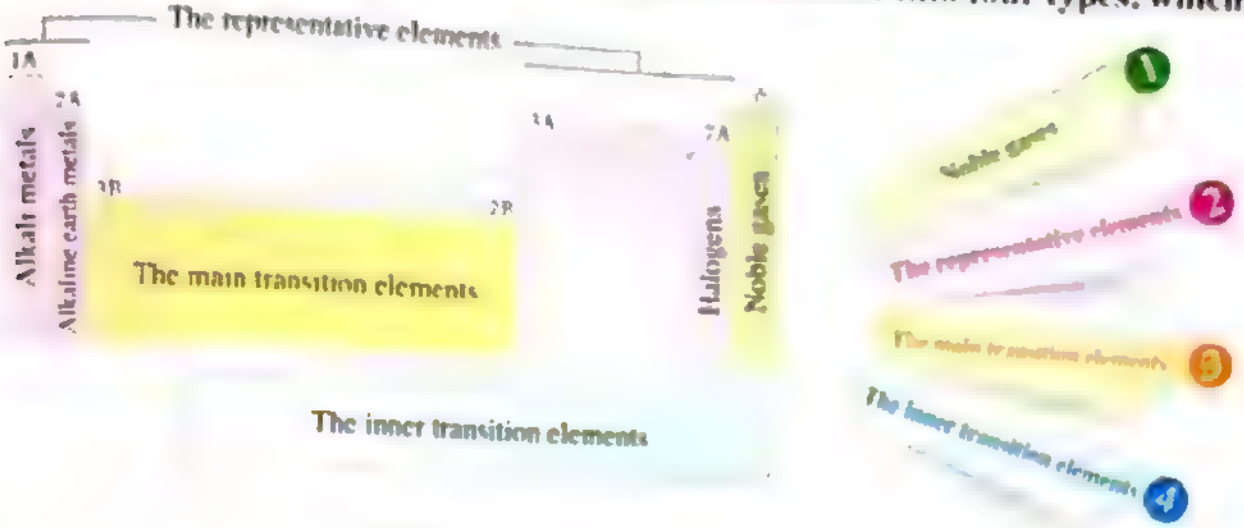
The block	s	p	d	f
The sublevel which is successively filled	s	p	d	f
Number of the orbitals of the sublevel	1	3	5	7
Number of the electrons required to saturate each sublevel	$1 \times 2 = 2e^-$	$3 \times 2 = 6e^-$	$5 \times 2 = 10e^-$	$7 \times 2 = 14e^-$
Number of the elements of each block in the sixth period	2	6	10	14

It is shown in the table that the number of the elements of f-block is 14 elements, this is the largest number of elements in the sixth period.

Answer : The correct choice is (d)

The types of the periodic table elements

- It is possible to classify the elements in the periodic table into four types, which are :



The types of the periodic table elements

Included information

Some significant gr...
the periodic table are ...
with characteristic ...
as in the opposite ...

Number of group	The characteristic name of the group
1A	Alkali metals
2A	Alkaline earth metals
7A	Halogens
0	Noble gases

1 Noble gases

- They are the elements of group zero "18" which is the last column of p-block.
- They are characterized by having energy levels completely filled with electrons and their electronic configurations end with np^6, except that of helium $_2He$ which ends with $1s^2$

Noble gases

Note

Noble gases may form compounds, but with great difficulty, because they are very stable elements as their energy levels are completely filled with electrons.

Worked Example

If the principal quantum number of the last electron in the atom of a noble gas is (n = 3). What is the number of the orbitals which are completely filled with electrons in this atom ?

(a) 3 (b) 5 (c) 7 (d) 9

Idea of answering :

∵ This element is a noble element.

∴ All the energy level in its atom are filled with electrons.

∵ The principal quantum number of its last electron is 3

∴ The electronic configuration of this atom is : $1s^2, 2s^2, 2p^6, 3s^2, 3p^6$

∴ The number of the filled orbitals = 1 + 1 + 3 + 1 + 3 = 9

Answer : The correct choice is (d)

Test Yourself

What is the number of the natural noble gase(s) in which $1s$ orbital is filled with electrons?

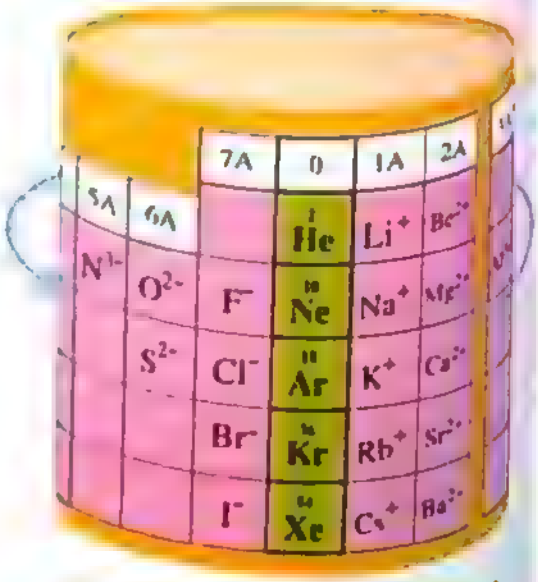
(a) 1 (b) 3

(c) 5 (d) 6

Answer : The correct choice is ....

2 The representative elements

- They are the elements of s and p-blocks, except that of group zero.
- They occupy the groups from 1A : 7A
- These elements are characterized by the complete filling of all the energy levels with electrons, except for the outermost level.
- They are active elements, because their outermost energy level tends to reach the completed electronic configuration similar to that of the nearest noble gas ($1s^2$ or ns^2, np^6) by gaining, losing or sharing electrons.



The representative elements tend to reach the electron configuration of the nearest noble gas

Examples

$$_{11}Na \xrightarrow[\text{1 electron}]{\text{loses}} Na^{+}$$

$1s^2 , 2s^2 , 2p^6 , 3s^1$ → $1s^2 , 2s^2 , 2p^6$

(Similar to the electronic configuration of neon gas $_{10}Ne$)

$$_{16}S \xrightarrow[\text{2 electrons}]{\text{gains}} S^{2-}$$

$1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^4$ → $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6$

(Similar to the electronic configuration of argon gas $_{18}Ar$)

Representative elements is the topic of Chapter 4 second term

$$_1H \; + \; _1H \xrightarrow{\text{sharing}} H_2$$

$1s^1$ $\quad$ $1s^1$ → $1s^2$

(Similar to the electronic configuration of helium gas $_2He$)

3 The main transition elements

- They are the elements of the d-block.
- They are characterized by having energy levels completely filled with electrons, except the outermost two levels.

Transition elements will be thoroughly discussed next year

* **Example :** $_{21}$**Sc :** $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2 , 3d^1$
  - **In the principal level (n = 4) :** The sublevel $4p$ is vacant.
  - **In the principal level (n = 3) :** The sublevel $3d$ is incompletely filled.

4 The inner transition elements

- They are the elements of the f-block.
- They are characterized by having energy levels completely filled with electrons, except the outermost three levels.

* **Example :** $_{64}$**Gd :** $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2 , 3d^{10} , 4p^6 , 5s^2 , 4d^{10} , 5p^6 , 6s^2 , 4f^7 , 5d^1$
  - **In the principal level (n = 4) :** The sublevel $4f$ is incompletely filled.
  - **In the principal level (n = 5) :** The sublevel $5d$ is incompletely filled.
  - **In the principal level (n = 6) :** The sublevel $6p$ is vacant.

Test Yourself

(1) What is the type of the element whose atom has an electronic configuration ends with : .... , $4f^{14}, 5d^{0}, 6s^{1}$?

ⓐ An inner transition element.
ⓑ A main transition element.
ⓒ A representative element.
ⓓ A noble element.

Idea of answering :

∵ The two outer principal energy levels .... and .... are not completely filled with electrons.

∴ The element is ....

Answer : The correct choice is ....

---

(2) What is the total number of the inner transition elements in both the fourth and the fifth periods in the periodic table ?

ⓐ Zero
ⓑ 14
ⓓ 28

Idea of answering :

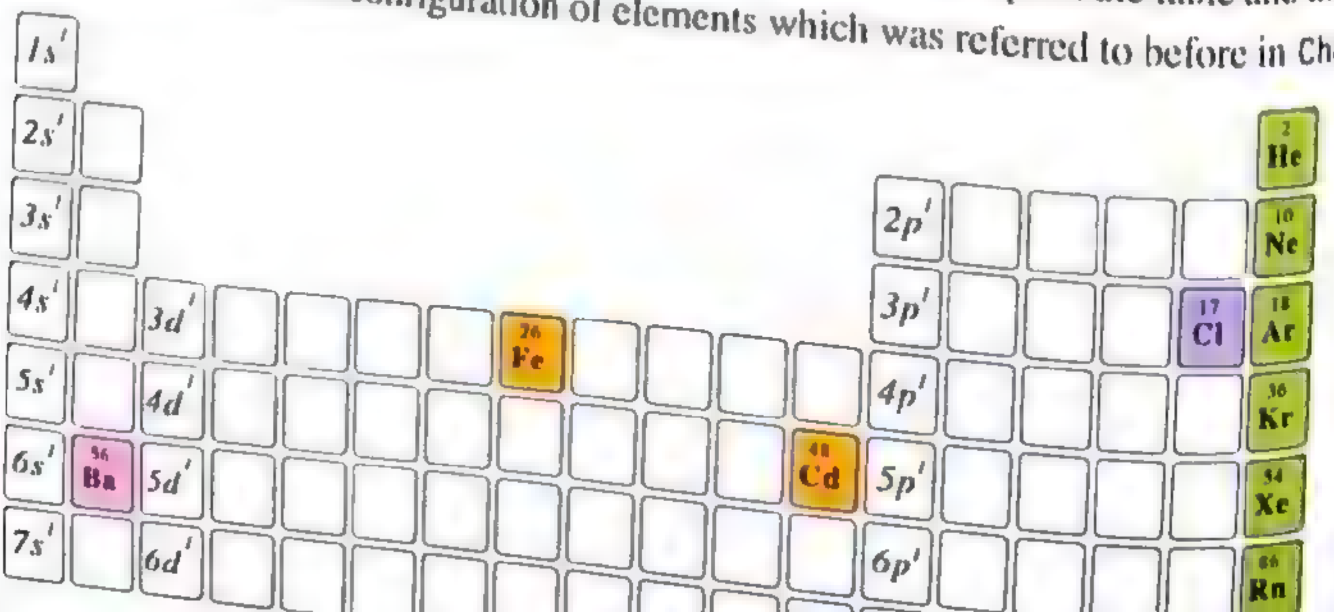
∵ Inner transition elements start to appear in the period.

∴ Number of the inner transition elements in both the 4^{th} and the 5^{th} periods = ...

Answer : The correct choice is ⓐ

The electronic configuration in the light of the modern periodic table

- The periodic table shows a method to express the electronic configurations of the elements according to the nearest noble gas which precedes the element in the periodic table and this is the method of the electronic configuration of elements which was referred to before in Chapter 1



- **The following table shows the electronic configurations of the atoms of the illustrated elements in the previous periodic table :**

The ordinary electronic configuration	Electronic configuration to the nearest noble gas
$_{17}Cl : 1s^2, 2s^2, 2p^6, 3s^2, 3p^5$	$_{17}Cl : [_{10}Ne], 3s^2, 3p^5$
$_{26}Fe : 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^6$	$_{26}Fe : [_{18}Ar], 4s^2, 3d^6$
$_{48}Cd : 1s^2, 2s^2, 2p$ [illegible] $4s^2, 3d^{10}, 4p^6, 5s^2, 4d^{10}$	$_{48}Cd : [_{36}Kr], 5s^2, 4d^{10}$
$_{56}Ba : 1s^2, 2s^2, 2p^6$ [illegible] $, 4s^2, 3d^{10}, 4p^6, 5s^2, 4d^{10}, 5p^6, 6s^2$	$_{56}Ba : [_{54}Xe], 6s^2$

Test Yourself

What is the block of the element whose atom has the electronic configuration :

$[Kr], 4d^{10}, 4f^4, 5s^2, 5p^6, 6s^2$?

(a) s-block.

(b) p-block.

(c) d-block.

(d) f-block.

Idea of answering :

∵ In this atom, the sublevel .... is not completely filled.

∴ The element belongs to .... block.

Answer : The correct choice is ....

The abnormality of the electron configurations of some elements in the periodic table

Chromium element ($_{24}Cr$) | **Copper element ($_{29}Cu$)**

Hypothetical electronic configuration

$_{24}Cr : [_{18}Ar] , 4s^2 , 3d^4$ ✘ $_{29}Cu : [_{18}Ar] , 4s^2 , 3d^9$

Actual electronic configuration

$_{24}Cr : [_{18}Ar] , 4s^1 , 3d^5$ ✓ $_{29}Cu : [_{18}Ar] , 4s^1 , 3d^{10}$

Explanation

The atom becomes more stable when the d sublevel is :

Half filled

$3d^5$ ↑ | ↑ | ↑ | ↑ | ↑

or

Completely filled

$3d^{10}$ ↑↓ | ↑↓ | ↑↓ | ↑↓ | ↑↓

- **By the same way** the electronic configuration of both molybdenum ($_{42}Mo$) and gadolinium ($_{64}Gd$).

Test Yourself

Is it possible that the sublevel *3d* in each of the atoms of 2 elements in the fourth period contains 5 single (unpaired) electrons ? Explain your answer.

....

....

- **The following table represents the electron configurations of the atoms of some elements of the modern periodic table in their ground states :**

Atomic number	Element	Electron configuration
1	H	$1s^1$
2	He	$1s^2$ = [He]
3	Li	[He] , $2s^1$
4	Be	[He] , $2s^2$
5	B	[He] , $2s^2$, $2p^1$
6	C	[He] , $2s^2$, $2p^2$
7	N	[He] , $2s^2$, $2p^3$
8	O	[He] [illegible] $2p^4$
9	F	[illegible]
10	Ne	[illegible] = [Ne]
11	Na	[illegible]
12	Mg	[illegible]
13	Al	[Ne] , $3s^2$, $3p^1$
14	Si	[Ne] , $3s^2$, $3p^2$
15	P	[Ne] , $3s^2$, $3p^3$
16	S	[Ne] , $3s^2$, $3p^4$
17	Cl	[Ne] , $3s^2$, $3p^5$
18	Ar	[Ne] , $3s^2$, $3p^6$ = [Ar]
19	K	[Ar] , $4s^1$
20	Ca	[Ar] , $4s^2$
21	Sc	[Ar] , $3d^1$, $4s^2$
22	Ti	[Ar] , $3d^2$, $4s^2$
23	V	[Ar] , $3d^3$, $4s^2$
24	Cr	[Ar] , $3d^5$, $4s^1$
25	Mn	[Ar] , $3d^5$, $4s^2$

Atomic number	Element	Electron configuration
26	Fe	[Ar] , $3d^6$, $4s^2$
27	Co	[Ar] , $3d^7$, $4s^2$
28	Ni	[Ar] , $3d^8$, $4s^2$
29	Cu	[Ar] , $3d^{10}$, $4s^1$
30	Zn	[Ar] , $3d^{10}$, $4s^2$
31	Ga	[Ar] , $3d^{10}$, $4s^2$, $4p^1$
32	Ge	[Ar] , $3d^{10}$, $4s^2$, $4p^2$
33	As	[Ar] , $3d^{10}$, $4s^2$, $4p^3$
34	Se	[Ar] , $3d^{10}$, $4s^2$, $4p^4$
35	Br	[Ar] , $3d^{10}$, $4s^2$, $4p^5$
36	Kr	[Ar] , $3d^{10}$, $4s^2$, $4p^6$ = [Kr]
37	Rb	[Kr] , $5s^1$
38	Sr	[Kr] , $5s^2$
39	Y	[Kr] , $4d^1$, $5s^2$
40	Zr	[Kr] , $4d^2$, $5s^2$
41	Nb	[Kr] , $4d^4$, $5s^1$
42	Mo	[Kr] , $4d^5$, $5s^1$
43	Tc	[Kr] , $4d^5$, $5s^2$
44	Ru	[Kr] , $4d^7$, $5s^1$
45	Rh	[Kr] , $4d^8$, $5s^1$
46	Pd	[Kr] , $4d^{10}$
47	Ag	[Kr] , $4d^{10}$, $5s^1$
48	Cd	[Kr] , $4d^{10}$, $5s^2$
49	In	[Kr] , $4d^{10}$, $5s^2$, $5p^1$
50	Sn	[Kr] , $4d^{10}$, $5s^2$, $5p^2$

Atomic number	Element	Electron configuration
51	Sb	[Kr], $4d^{10}, 5s^2, 5p^3$
52	Te	[Kr], $4d^{10}, 5s^2, 5p^4$
53	I	[Kr], $4d^{10}, 5s^2, 5p^5$
54	Xe	[Kr], $4d^{10}, 5s^2, 5p^6$ = [Xe]
55	Cs	[Xe], $6s^1$
56	Ba	[Xe], $6s^2$
57	La	[Xe], $5d^1, 6s^2$
58	Ce	[Xe], $4f^1, 5d^1, 6s^2$
59	Pr	[Xe], $4f^3, 6s^2$
60	Nd	[Xe], $4f^4, 6s^2$
61	Pm	[Xe], $4f^5, 6s^2$
62	Sm	[Xe], $4f^6, 6s^2$
63	Eu	[Xe], $4f^7, 6s^2$
64	Gd	[Xe], $4f^7, 5d^1, 6s^2$
65	Tb	[Xe], $4f^9, 6s^2$
66	Dy	[Xe], $4f^{10}, 6s^2$
67	Ho	[Xe], $4f^{11}, 6s^2$
68	Er	[Xe], $4f^{12}, 6s^2$
69	Tm	[Xe], $4f^{13}, 6s^2$
70	Yb	[Xe], $4f^{14}, 6s^2$
71	Lu	[Xe], $4f^{14}, 5d^1, 6s^2$
72	Hf	[Xe], $4f^{14}, 5d^2, 6s^2$
73	Ta	[Xe], $4f^{14}, 5d^3, 6s^2$
74	W	[Xe], $4f^{14}, 5d^4, 6s^2$
75	Re	[Xe], $4f^{14}, 5d^5, 6s^2$
76	Os	[Xe], $4f^{14}, 5d^6, 6s^2$
77	Ir	[Xe], $4f^{14}, 5d^7, 6s^2$
78	Pt	[Xe], $4f^{14}, 5d^9, 6s^1$
79	Au	[Xe], $4f^{14}, 5d^{10}$ [illegible]
80	Hg	[Xe], $4f^{14}, 5d^{10}$ [illegible]
81	Tl	[Xe], $4f^{14}, 5d^{10}$ [illegible]
82	Pb	[Xe], $4f^{14}, 5d^{10}$ [illegible]
83	Bi	[Xe], $4f^{14}, 5d^{10}$ [illegible]
84	Po	[Xe], $4f^{14}, 5d^{10}, 6s^2, 6p^4$
85	[illegible]	[Xe], $4f^{14}, 5d^{10}, 6s^2, 6p^5$
86	[illegible]	[Xe], $4f^{14}, 5d^{10}, 6s^2, 6p^6$ = [Rn]
87	[illegible]	[Rn], $7s^1$
88	[illegible]	[Rn], $7s^2$
89	Ac	[Rn], $6d^1, 7s^2$
90	Th	[Rn], $6d^2, 7s^2$
91	Pa	[Rn], $5f^2, 6d^1, 7s^2$
92	U	[Rn], $5f^3, 6d^1, 7s^2$
93	Np	[Rn], $5f^4, 6d^1, 7s^2$
94	Pu	[Rn], $5f^6, 7s^2$
95	Am	[Rn], $5f^7, 7s^2$
96	Cm	[Rn], $5f^7, 6d^1, 7s^2$
97	Bk	[Rn], $5f^9, 7s^2$
98	Cf	[Rn], $5f^{10}, 7s^2$
99	Es	[Rn], $5f^{11}, 7s^2$
100	Fm	[Rn], $5f^{12}, 7s^2$
101	Md	[Rn], $5f^{13}, 7s^2$
102	No	[Rn], $5f^{14}, 7s^2$
103	Lr	[Rn], $5f^{14}, 6d^1, 7s^2$

Determination of element location in the periodic table

- **Period number :**

It is determined by the highest principal quantum number (n) in the electronic configuration of the element.

- **Group number and symbol :**

They are determined by the type of element **as shown in the following table :**

Type of element	Block	Electronic configuration	Group number	Group symbol
Representative	s	$ns^{1:2}$	The number of electrons of the last sublevel (s)	(A)
Representative	p	[illegible]	The sum of the numbers of electrons in the last two sublevels (s) and (p) "Excluding group zero"	(A)
Noble gases	p	np^6	Group zero (p sublevel is completely filled with electrons) "In addition to $_2He$"	–
Main transition	d	$ns^{1:2}$, $(n-1)d^{1:10}$	The sum of the numbers of electrons in the last (s) sublevel and the penultimate (d) sublevel, as follows :	(B) Excluding group 8

Total number of electrons of ns , $(n-1)d$	Group number
3 : 7	3B : 7B
8 : 10	8
11	1B
12	2B

Worked Examples

1 **Illustrate the block, type and location of the following elements in the periodic ta**

(1) $_{12}Mg$ (2) $_{32}Ge$

(3) $_{36}Kr$ (4) $_{25}Mn$

(5) $_{29}Cu$

Answer :

	Element	Electron configuration	Block	Type of element	Period number	Group number
(1)	$_{12}Mg$	$[_{10}Ne], 3s^2$	s	Representative	3	2A
(2)	$_{32}Ge$	$[_{18}Ar], 4s^2, 3d^{10}, 4p^2$	p	Representative	4	4A
(3)	$_{36}Kr$	$[_{18}Ar], 4s^2, 3d^{10}, 4p^6$	p	Noble gas	4	zero
(4)	$_{25}Mn$	$[_{18}Ar], 4s^2, 3d^5$	d	Main transition	4	7B
(5)	$_{29}Cu$	$[_{18}Ar], 4s^1, 3d^{10}$	d	Main transition	4	1B

2 **A representative element contains four principal energy levels occupied b... the last sublevel has three unpaired electrons.**

Determine each of the following :

(1) The electron configuration of its atom.

(2) Its atomic number.

(3) Number of completely filled orbitals in the outermost energy level.

(4) Number of valence electrons.

Answer :

(1) $[Ar], 4s^2, 3d^{10}, 4p^3$

(2) 33

(3) 1 orbital.

(4) 5 electrons.

Test Yourself

Two elements (X) and (Z) are located in group 6A, if the element (X) is located in the third period, and the element (Z) is located in the fifth period.

What is the atomic number of the element (Y) which lies between them in the same group ?

ⓐ 31

ⓑ 32

ⓒ 33

ⓓ 34

Idea of answering :

∵ Element (X) is located in the third period, and element (Z) in the fifth period.

∴ Element (Y) is located in the .... period.

∵ The electronic configuration of the atom of this element is :

$$[Ar], 4s^{...}, 3d^{10}, 4p^{...}$$

∴ The atomic number of element (Y) = ... + ... + ... + ...

= ....

Answer : The correct choice is ....

Ready

Preliminary questions to remember the principal concepts in the le

Answer them y

1 Choose from (B) and (C) what is suitable for (A) :

(A)	(B)	(C)
Element	**The electronic configuration of the outermost level**	**Type of element**
(1) Radon $_{86}Rn$	(a) $5s^1, 4d^5$	(1) Inner transition (an actinide
(2) Cesium $_{55}Cs$	(b) $6s^2, 4f^{14}, 5d^6$	(2) Main transition (second trans series).
(3) Bromine $_{35}Br$	(c) $6s^2, 4f^{14}, 5d^{10}, 6p^6$	(3) Noble.
(4) Vanadium $_{23}V$	(d) $4s^2, 3d^3$	(4) Main transition (third series).
(5) Molybdenum $_{42}Mo$	(e) $6s^2, 4f^7, 5d^1$	(5) Inner transition (a lant
(6) Osmium $_{76}Os$	(f) $4s^2, 3d^{10}, 4p^5$	(6) Representative (s-bloc
(7) Gadolinium $_{64}Gd$	(g) $6s^2, 4f^8$	(7) Main transition (first t series).
	(h) $6s^1$	(8) Representative (p-block

2 Choose the correct answer for each of the following sentences :

(1) The elements of the same period are similar in the number of ....

a. valence electrons.

b. protons.

c. energy levels.

d. neutrons.

(2) Which of the following elements is located in the same period of silicon $_{14}Si$ in the modern periodic table ?

a. $_{32}Ge$
b. $_{21}Sc$
c. $_{11}Na$
d. $_{38}Sr$

(3) The element whose atomic number is 5 has similar properties to those of the element with the atomic number ....

a. 8
b. 13
c. 14
d. 19

(4) The molecule of the element whose electronic configuration ends with np^6 consists of ....

a. one atom.
b. two atoms.
c. three atoms.
d. four atoms.

(5) The element which is located at the top right of the modern periodic table is a ....

a. representative element.
b. noble element.
c. main transition element.
d. metallic element.

(6) What is the type of the elements whose last electronic configuration is : ns^2 , $np^{1:5}$?

a. Representative.
b. Main transition.
c. Inner transition.
d. Noble.

(7) What is the number of the elements of f-block ?

a. 32
b. 46
c. 28
d. 14

(8) What is the sublevel which is successively filled with electrons in the series of actinides ?

a. *3d*
b. *4d*
c. *4f*
d. *5f*

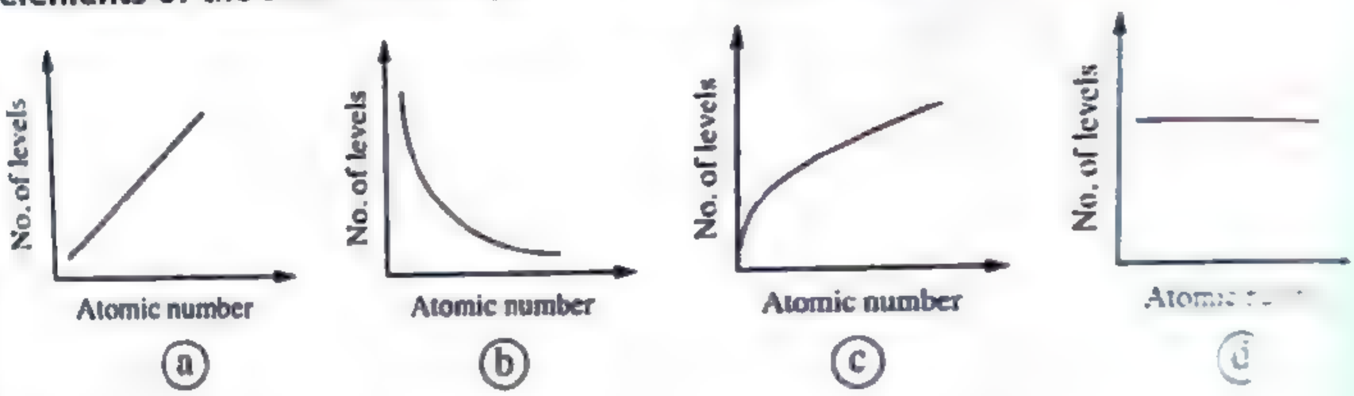
(9) There is an abnormality in the electronic configuration of each of ....

a. $_{24}Cr^{3+}$, $_{26}Fe^{3+}$
b. $_{48}Cd$, $_{30}Zn$
c. $_{29}Cu^{+}$, $_{29}Cu$
d. $_{24}Cr$, $_{29}Cu$

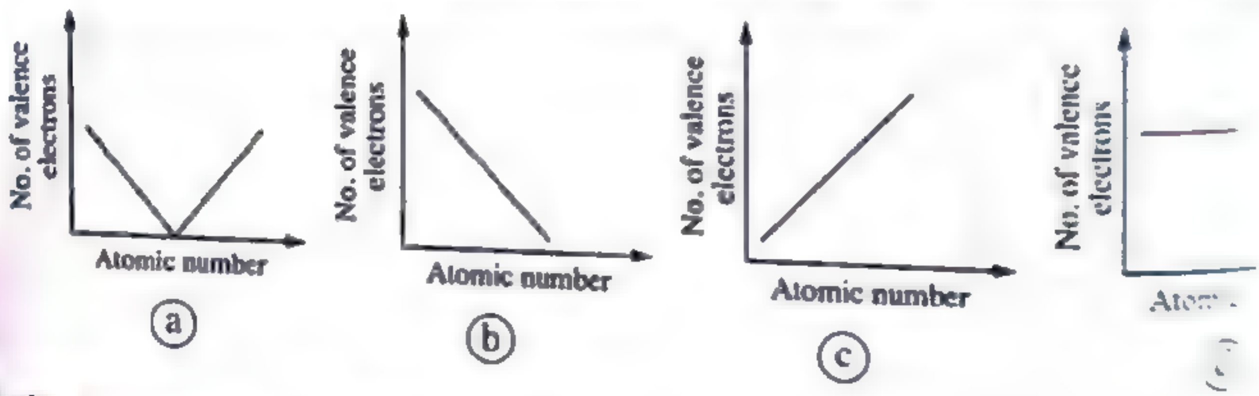
Multiple choice questions

Modern periodic table

1 Which of the following graphical figures represents the relation between num... of principal energy levels occupied with electrons and the atomic number of the elements of the same vertical group in the periodic table ?



2 Which of the following graphical figures represents the relation between nu... valence electrons and the atomic number of the elements of the same gro...



3 The properties of the two elements .... are similar.

ⓐ $_{19}K$, $_{20}Ca$
ⓑ $_{31}Ga$, $_{32}Ge$
ⓒ $_{17}Cl$, $_{35}Br$
ⓓ $_{55}Cs$, $_{56}Ba$

4 The chemical properties of both cesium $_{55}Cs$ and element X are similar. What is the electron configuration of element X ?

ⓐ $1s^1$
ⓑ [Xe] , $6s^2$
ⓒ [Ar] , $3d^5$, $4s^1$
ⓓ [Ar] , $3d^{10}$, $4s^2$, $4p^6$, $5s^1$

5 What is the number of the periods in the periodic table which lie between the periods of hydrogen element ($_1H$) and argon element ($_{18}Ar$) ?

ⓐ zero.
ⓑ 1 period.
ⓒ 2 periods.
ⓓ 3 periods.

The elements blocks of the modern periodic table

6 Which of the following are the quantum numbers of the last electron in an element that belongs to p–block ?

ⓐ $n = 2 , \ell = 0 , m_\ell = 0 , m_s = -\frac{1}{2}$
ⓑ $n = 1 , \ell = 0 , m_\ell = 0 , m_s = -\frac{1}{2}$
ⓒ $n = 1 , \ell = 1 , m_\ell = +1 , m_s = +\frac{1}{2}$
ⓓ $n = 3 , \ell = 2 , m_\ell = +1 , m_s = +\frac{1}{2}$

7 What is the atomic number of the second element in d-block elements, which is located in the fourth period ?

ⓐ 12
ⓑ 22
ⓒ 38
ⓓ 39

8 What is the electronic configuration of the elements of the penultimate column of d-block ?

ⓐ $(n-1)d^1 , ns^1$
ⓑ $(n-2)d^1 , ns^1$
ⓒ $(n-1)d^2 , ns^2$
ⓓ $(n-1)d^{10} , ns^1$

9 The elements which follow neon gas ($_{10}Ne$) and precede rubidium element ($_{37}Rb$) are located in ....

ⓐ the third period only.
ⓑ the fourth period only.
ⓒ the third and the fourth periods.
ⓓ the fourth and the fifth periods.

The types of the periodic table elements

10 Which of the following elements differs in the electronic configuration of its valence shell from the other elements in its group ?

ⓐ $_{36}Kr$
ⓑ $_{19}K$
ⓒ $_4Be$
ⓓ $_2He$

11 What is the type of the element that the last electron in its atom has the two quantum numbers $\left(\ell = 1 , m_s = +\frac{1}{2}\right)$?

(a) Representative only.
(b) Noble only.
(c) Representative or noble.
(d) Representative or main transition

12 Which of the following choices represents the electronic configuration of an alkaline earth metal ?

(a) [Ar] , $4s^1$, $3d^5$
(b) [Ar] , $4s^2$, $3d^6$
(c) [Rn] , $7s^2$
(d) [Xe] , $6s^2$, $5d^1$, $4f^7$

13 Which of the following choices represents the electronic configuration of a transition element ?

(a) $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 3d^{10} , 4s^2 , 4p^6$
(b) $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 3d^{10} , 4s^2 , 4p^1$
(c) $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2 , 3d^2$
(d) $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2$

14 Actinides are similar to lanthanides in ....

(a) the successive filling of $4f$ sublevel.
(b) the instability of their nuclei.
(c) that it is impossible to determine the numbers of their groups.
(d) their location in the sixth period.

15 What is the difference in number between the representative elements in the second period and those in the third period ?

(a) 0
(b) 2
(c) 8
(d) 10

The electronic configuration in the light of the modern periodic table

16 All the following are among the properties of the elements $_4Be$, $_{12}Mg$ and $_{20}$(, except that ....

(a) the last sublevel s contains 2 electrons.
(b) the sublevel p in the valence shell contains a pair of electrons.
(c) they are representative elements.
(d) they are located in group (2...

17 What is the type of the element which contains 2 electrons in the sublevel whose value of the quantum number (l) is 2 ?

ⓐ Main transition. ⓑ Inner transition.

ⓒ Noble. ⓓ Representative.

18 What is the type of the element whose electronic configuration is : [Xe] , $6s^2$, $4f^{14}$, $5d^7$?

ⓐ Main transition element. ⓑ Inner transition element.

ⓒ Representative element. ⓓ Noble element.

19 The following figure represents a section in the modern periodic table.

Li	Be														O	F	Ne
Na	Mg														S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr															I	Xe
Cs	Ba															At	Rn

What is the number of each of the representative and the transition elements in this section ?

Choices	Number of representative elements	Number of transition elements
ⓐ	21	10
ⓑ	10	10
ⓒ	26	5
ⓓ	5	10

20 The electronic configuration of silver $_{47}Ag$ is ....

ⓐ [Ar] , $4s^2$, $4d^9$ ⓑ [Kr] , $5s^1$, $4d^{10}$

ⓒ [Kr] , $5s^2$, $3d^9$ ⓓ [Ar] , $4s^1$, $4d^{10}$

21 An element with atomic number 42, the number of its half filled orbitals is ....

ⓐ 1 ⓑ 4

ⓒ 5 ⓓ 6

22 The two electronic configurations are similar in ....

(a) Na and Ne
(b) Na^+ and Mg^{2+}
(c) Mg^+ and Ne
(d) Mg^{2+} and Na

23 What is the compound in which the number of electrons of its positive ion eq. the number of electrons of its negative ion ?

(a) $MgCl_2$
(b) NaCl
(c) MgO
(d) MgS

24 Which of the following represents the location of the element $_{73}X$ in the modern periodic table ?

Choices	Period	Group
(a)	5	7
(b)	6	13
(c)	6	5
(d)	5	5

25 The electronic configuration of ruthenium ion $_{44}Ru^{3+}$ is ....

(a) [Kr] , $4d^3$, $5s^2$
(b) [Kr] , $4d^6$, $5s^2$
(c) [Kr] , $4d^5$
(d) [Kr] , $4d^6$

26 Which of the following statements represents properly the element which in period 3, group (VIIA) in the modern periodic table ?

(a) It forms an ion whose charge is +1
(b) It is one of d-block elements.
(c) Its valence shell contains 5 electrons.
(d) It is a representative element which is located below fluorine $_9F$

27 Sr element is located in the fifth period, group (2A) in the periodic table. What is the electronic configuration of its ion ?

(a) [Ar] , $4s^2$, $3d^{10}$, $4p^6$
(b) [Ar] , $4s^2$
(c) [Kr] , $5s^2$, $4d^{10}$, $5p^4$
(d) [Kr] , $5s^2$

28 An element in the period (n) and group (5B).

Which of the following represents the electronic configuration of its outer energy levels ?

(a) $ns^2, (n-2)f^{14}, (n-1)d^5$

(b) $ns^2, (n-1)f^{14}, (n-1)d^3$

(c) $ns^2, (n-2)f^{14}, (n-1)d^3$

(d) $ns^2, (n-2)f^{14}, nd^3$

29 What is the atomic number of the element (X) whose electronic configuration ends with : $ns^1, (n-1)d^5$ and its electrons are distributed in 5 principal energy levels ?

(a) 29

(b) 24

(c) 47

(d) 42

30 If the element (X) in the periodic table forms the compounds XCl_3 , X_2O_3 then (X) is located in group ....

(a) IIIA

(b) IA

(c) IVA

(d) VIIA

31 The electron configuration of the positive ion of the compound MO ends with the sublevel $2p^6$

Which of the following determines the location of element M in the modern periodic table ?

Choices	Period	Group
(a)	The fourth	7
(b)	The fourth	9
(c)	The third	16
(d)	The third	2

32 A divalent representative element is located in p-block in the periodic table.

What is the number of the half filled orbitals in the atom of this element ?

(a) 1

(b) 2

(c) 3

(d) 4

33 What is the type of the trivalent metal whose ion has the electronic configuration : [Ar] ?

(a) Main transition.

(b) Inner transition.

(c) Inert.

(d) Representative.

34 An element is located in the third period, if its atom loses one electron, then its last sublevel becomes half filled with electrons.
What is the symbol of this element ?

ⓐ $_{13}Al$
ⓑ $_{14}Si$
ⓒ $_{15}P$
ⓓ $_{16}S$

35 What are the possible quantum numbers of the last electron in the atom of an element which is located in the fourth period, group (7A) ?

ⓐ $n=4, l=1, m_l=0, m_s=-\frac{1}{2}$
ⓑ $n=4, l=3, m_l=-1, m_s=+\frac{1}{2}$
ⓒ $n=4, l=2, m_l=-2, m_s=+\frac{1}{2}$
ⓓ $n=3, l=0, m_l=0, m_s=+\frac{1}{2}$

36 If the four quantum numbers of the electron with the highest energy in the atom of a main transition element located in the period (X) are $(3, 2, +2, +\frac{1}{2})$, then the probable four quantum numbers of the last electron in the representative element which is located at the end of the period (X) are ....

ⓐ $4, 1, 0, -\frac{1}{2}$
ⓑ $3, 1, +1, +\frac{1}{2}$
ⓒ $4, 0, 0, +\frac{1}{2}$
ⓓ $3, 2, +2, -\frac{1}{2}$

37 The electrons of the atom of a representative element occupy 3 principal energy levels and its last sublevel contains a number of electrons double their number in its first principal level.
What is the atomic number of this element ?

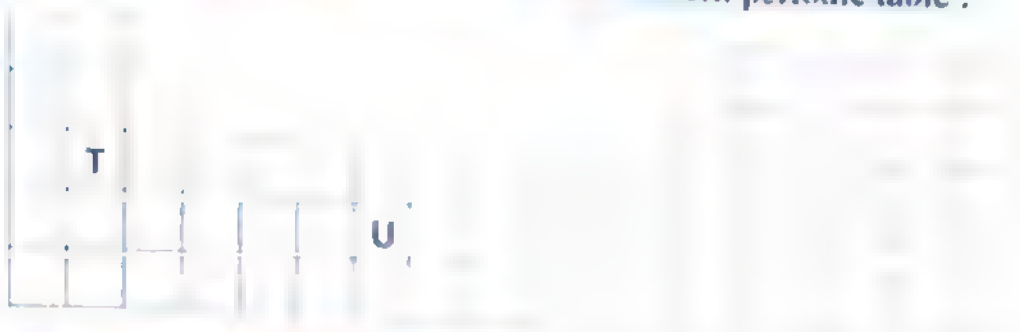
ⓐ 16
ⓑ 17
ⓒ 18
ⓓ 19

38 If the electronic configuration of an element atom is $[Xe], 6s^2, 5d^1, 4f^7$
Which of the following choices represents the distribution of the electrons in the principal energy levels ?

ⓐ 2 – 8 – 18 – 32 – 4
ⓑ 2 – 8 – 18 – 18 – 8 – 2
ⓒ 2 – 8 – 18 – 25 – 9 – 2
ⓓ 2 – 8 – 18 – 32 – 4

Essay questions

39 The following figure represents a section in the modern periodic table :



Conclude the difference between the atmoic numbers of the two elements U and T, with explanation.

40 An element (X) its electronic configuration ends as follows : ..... , $7s^2$, $6d^1$, $5f^4$

(1) What is the type of this element ?

(2) What is the number of the protons inside the nucleus of the atom of this element ?

41 Determine the block and the type of the elements which have the following electronic configurations :

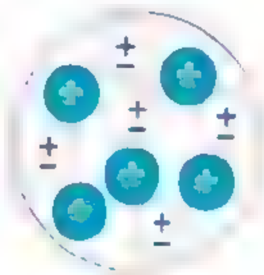
(1) [Ar] , $4s^2$, $3d^5$ (2) [Kr] , $5s^1$

42 Illustrate the electronic configuration of each of the following elements, with writing their atomic numbers :

(1) A representative element which is located in period 2, group 5A

(2) A noble element located in period 3

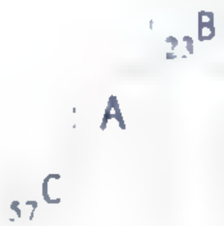
43 The opposite figure illustrates the atom of one of the elements :



(1) Write the electronic configuration of this element atom according to the nearest noble gas.

(2) Determine the location of this element in the periodic table.

44 The opposite figure represents a section in the periodic table. Deduce the atomic number of the element (A), with explanation.



45 Predict the general formula of the oxides of the representative elements of group (2A).

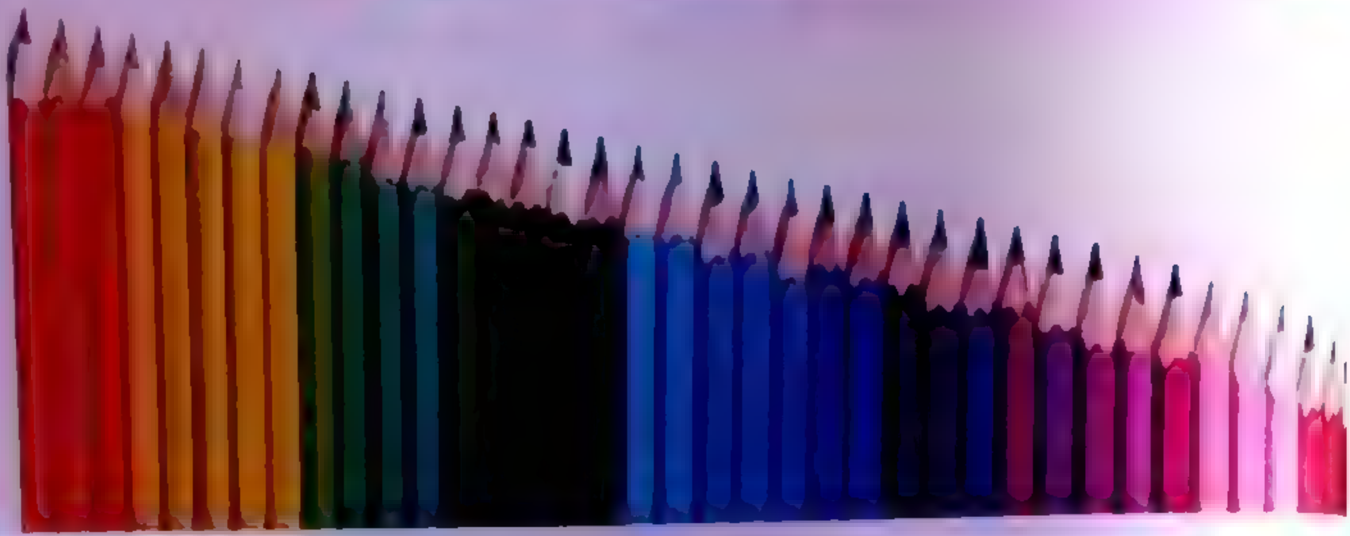
46 In the light of your knowledge of the quantum numbers. Why should the 6^{th} period contain 32 elements ?

Chapter 2

Lesson Two

From Trends and periodicity of properties in the periodic ...

Until Before metallic and nonmetallic property



The graduation of the representative elements properties

The chemical properties and some of the physical properties of the elements depend on their electronic configurations and especially on the valence electrons (the electrons which are found in the outermost principal level).

Group no. →	1A	2A	3A	4A	5A	6A	7A
	Li	Be	B	C	N	O	F
No. of valence electrons →	1	2	3	4	5	6	7

The numbers of the valence electrons of the elements in the second period

We will study the graduation of the following properties in the representative e...

1. **The atomic radius.**
2. **Ionization potential.**
3. **Electron affinity.**
4. **Electronegativity.**
5. **Metallic and nonmetallic property.**
6. **Acidic and basic property.**
7. **Oxidation numbers.**

1 The atomic radius

- The concept of bond length in the covalent compounds differs from that in the ionic compounds.
- By knowing the bond length, we can calculate :

A. **Atomic radius.**

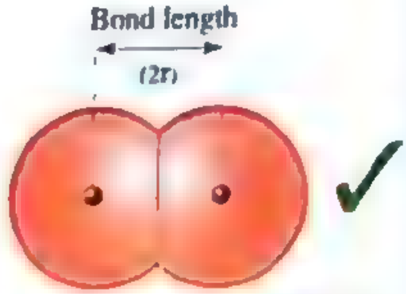
B. **Ionic radius.**

A Atomic radius

- The atomic radius cannot be estimated or measured physically by the distance between the nucleus and the farthest electron, because it is impossible to determine the precise location of an electron around the nucleus (as the wave mechanics theory revealed).

But the atomic radius can be calculated by knowing the covalent bond length which is estimated in angstroms (Å).

Wrong perception for the radius



Covalent bond length (2r) in a diatomic molecule

1 angstrom = 1×10^{-10} meter

Covalent bond length (2r)
is estimated by the distance between the centers of the two nuclei of two bonded atoms.

Atomic radius (r)
is estimated by half the distance between the centers of two similar atoms in a diatomic molecule.

Covalent bond length = Sum of the two atomic radii of the two atoms of the molecule

$$\text{The atomic radius (r)} = \frac{\text{Bond length in a diatomic element molecule (2r)}}{2}$$

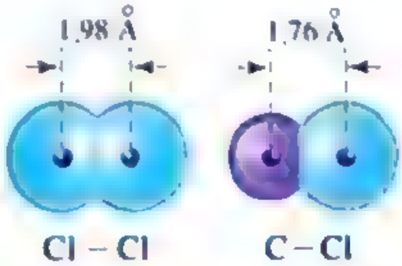
The following table shows the bond length and the covalent atomic radius for some molecules :

The molecule	H – H	F – F	Cl – Cl	Br – Br	I – I
The bond length (Å)	0.6	1.28	1.98	2.28	2.66
The covalent atomic radius (Å)	0.3	0.64	0.99	1.14	1.33

Worked Examples

1 If you know that :

- The bond length in chlorine molecule Cl_2 is 1.98 Å
- The bond length between carbon and chlorine atoms (C – Cl) in carbon tetrachloride CCl_4 is 1.76 Å



What is the atomic radius of carbon atom ?

ⓐ 0.22 Å ⓑ 0.77 Å ⓒ 0.99 Å ⓓ 1.21 Å

Idea of answering :

The atomic radius of chlorine = $\frac{\text{Bond length in chlorine molecule } Cl_2}{2}$

$$r(Cl) = \frac{1.98}{2} = 0.99 \text{ Å}$$

The atomic radius of carbon = The (C – Cl) bond length – The atomic radius of chl...

$$r(C) = 1.76 - 0.99 = 0.77 \text{ Å}$$

Answer : The correct choice is (b)

---

2 • The bond length in hydrogen molecule H_2 = 0.6 Å

• The bond length in nitrogen molecule N_2 = 1.4 Å

• The bond length in nitric oxide molecule NO = 1.36 Å

Calculate :

(1) The bond length in oxygen molecule O_2

(2) The bond length (O – H) in water molecule H_2O

Answer :

(1) The atomic radius of nitrogen = $\frac{\text{Bond length of } N_2 \text{ molecule}}{2}$

$$r(N) = \frac{1.4}{2} = 0.7 \text{ Å}$$

The atomic radius of oxygen = The (N – O) bond length – The atomic ra...

$$r(O) = 1.36 - 0.7 = 0.66 \text{ Å}$$

The bond length in oxygen molecule O_2 = 2 × The atomic radius of oxyg...

$$2r(O_2) = 2 \times 0.66 = 1.32 \text{ Å}$$

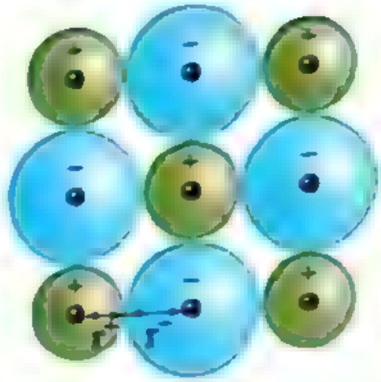
(2) The atomic radius of hydrogen = $\frac{\text{Bond length of } H_2 \text{ molecule}}{2}$

$$r(H) = \frac{0.6}{2} = 0.3 \text{ Å}$$

The bond length (O – H) = The atomic radius of oxygen + The atomic radius...

$$r(O) + r(H) = 0.66 + 0.3 = 0.96 \text{ Å}$$

B Ionic radius



Ionic bond length
sum of the radii of (cation + anion)

The ionic compounds such as sodium chloride are found in a crystalline form and consist of positive ions (cations) and negative ions (anions).

Ionic **bond length** is estimated by the distance between the centers of the nuclei of two bonded ions in the formula unit of the crystal.

The ionic bond length = The sum of two ionic radii in the formula unit

- **The ionic radius depends on the number of electrons lost or gained to form ions.**

Worked Example

- The ionic radius of lithium $(Li^+) = 0.68$ Å
- The ionic radius of sodium $(Na^+) = 0.98$ Å
- The bond length of sodium chloride formula unit $(Na^+Cl^-) = 2.76$ Å

What is the ionic bond length in lithium chloride formula unit ?

ⓐ 1.66 Å

ⓑ 1.78 Å

ⓒ 2.08 Å

ⓓ 2.46 Å

Idea of answering :

- The ionic radius of chloride ion Cl^- = The (Na^+Cl^-) bond length – The ionic radius of sodium

$$r(Cl^-) = 2.76 - 0.98 = 1.78 \text{ Å}$$

- The bond length in lithium chloride formula unit (Li^+Cl^-) =

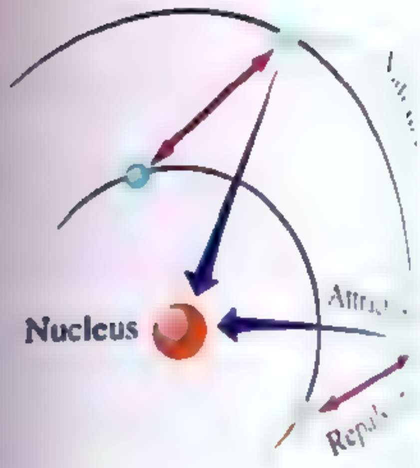
The ionic radius of lithium ion + The ionic radius of chloride ion

$$r(Li^+) + r(Cl^-) = 0.68 + 1.78 = 2.46 \text{ Å}$$

Answer : The correct choice is ⓓ

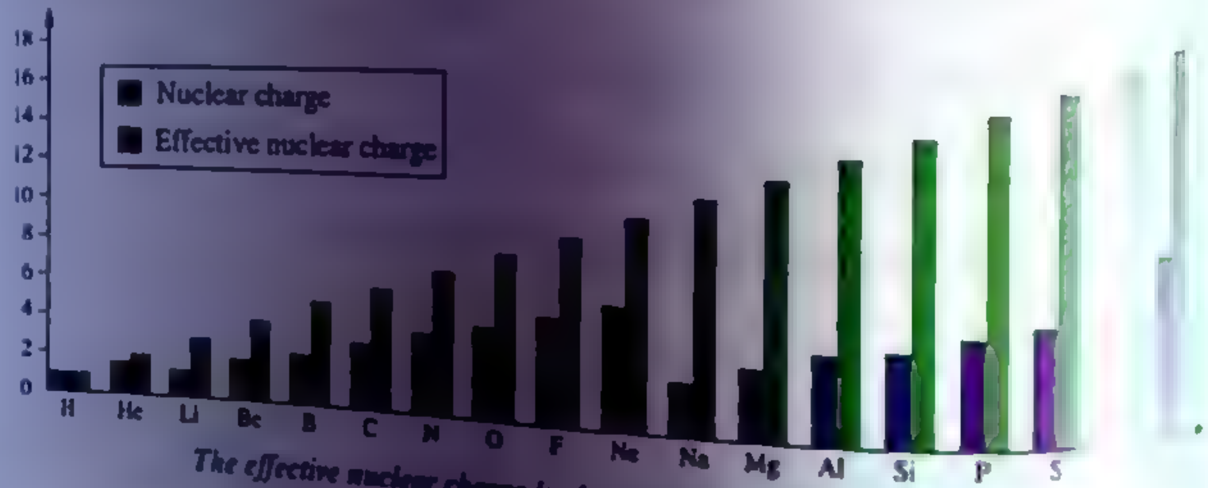
The effective nuclear charge concept (Z-effect)

- The valence electrons are not affected by the complete nuclear charge (the charge of the nucleus protons).
- This is because the inner electrons (core electrons of the inner energy levels) screen a part of this charge from the valence electrons (electrons of interest). So, the actual charge affecting any electron is called *the effective nuclear charge (Z_{eff})* *which is the actual nuclear charge (positive charge) that affects an electron in an atom.*



The attraction and repul... which affect the valence el...

- And the effective nuclear charge (Z_{eff}) is always less than the nuclear charge (the total number of protons present in a nucleus).



The effective nuclear charge is always less than the nuclear charge

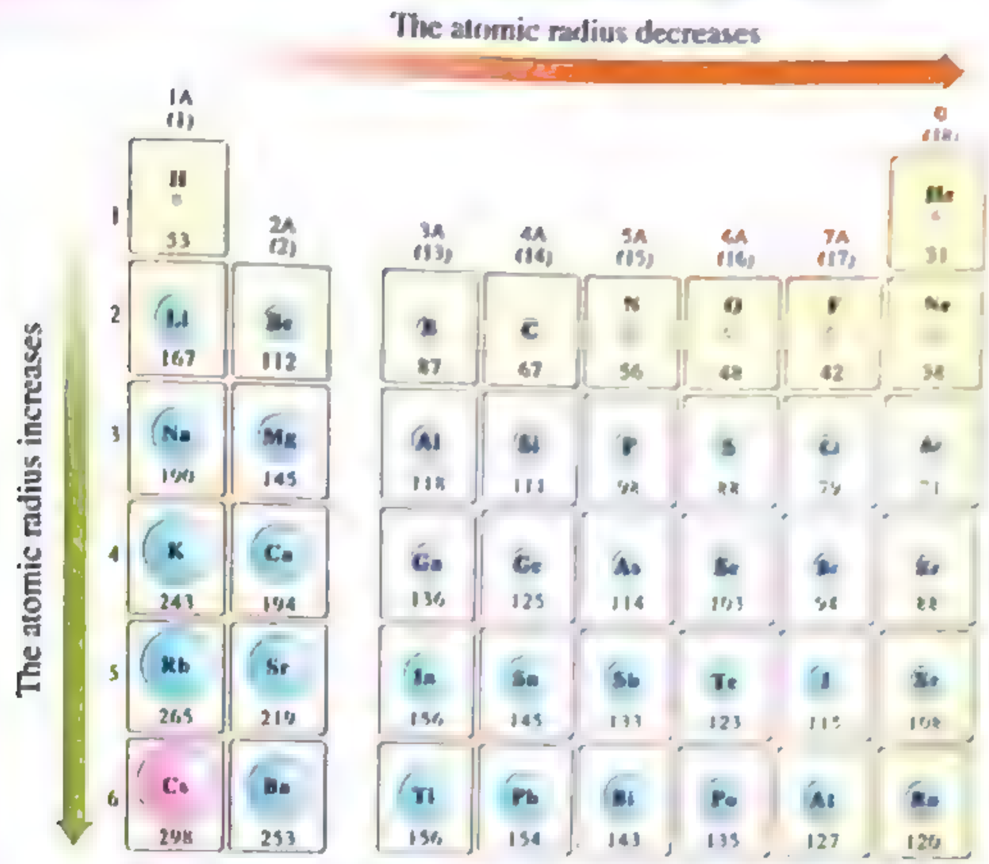
The element	Li	Be	B	C	N	O	[illegible]
Z	3	4	5	6	7	8	[illegible]
Z_{eff}	1.28	1.91	2.42	3.14	3.83	4.45	5.1

For illustration only

Note

In hydrogen atom, the effective nuclear charge (Z_{eff}) is equivalent to the charge of the nucleus (Z), as the atom contains one electron, and hence no other electrons ... to repel each other or to screen a part of the charge of the nucleus from this ...

The graduation of atomic radius in the periodic table



The graduation of atomic radius property in the elements of the two blocks s and p estimated in picometers (pm)

For illustration only

It can be observed from the figure that :

In the horizontal period	In the vertical group
The atomic radius decreases as we go from left to right across the same period by increasing the atomic number from 1A to group zero	The atomic radius increases as we go down the same group by increasing the atomic number from the first to the seventh period

Because the increase in the atomic number results in

The gradual increase in the effective nuclear charge (Z_{eff}) which increases the nuclear attraction to the valence electrons (pulling them closer to the nucleus) leading to the decrease in the atomic radius.	• The increase in the number of the energy levels in each new period. • The increase in the number of the completely filled energy levels that screen more of the effective nuclear charge from the outer electrons. • Increasing the repulsive forces between electrons.

General conclusion :

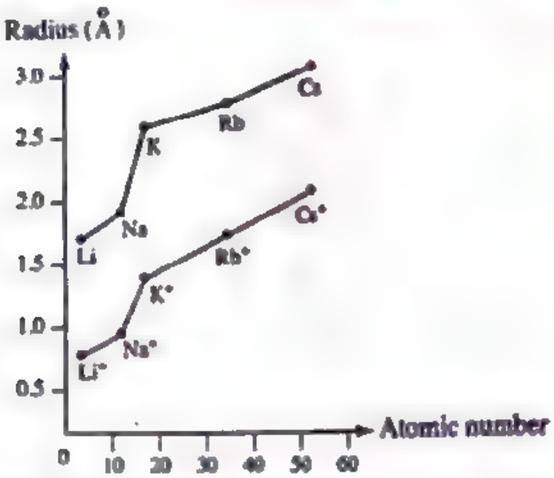
- The atoms of the first group elements (alkalis) are the biggest atoms, while the atoms of the seventh group elements (halogens) are the smallest atoms.
- The biggest element atom in size is cesium (Cs).

The relation between the radii of atoms and their ions

* The radii of atoms differ from the radii of their ions as shown in the following

Metals

* The metal atoms tend to lose their valence electrons during the chemical reaction to form positive ions.

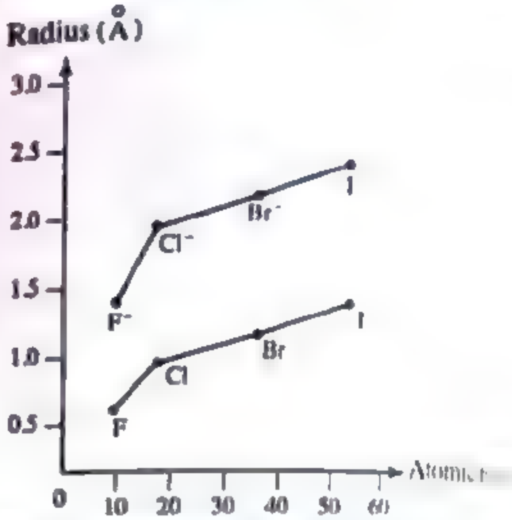


The relationship between metals radii and their positive ions

- The positive ion (the cation) radius is smaller than its atomic radius, as the number of positive protons in the cation is higher than the number of negative electrons. So the attraction of the effective nuclear charge to remaining electrons increases leading to decreasing the size.

Nonmetals

* The nonmetal atoms tend to gain electrons during the chemical reaction to form negative ions.

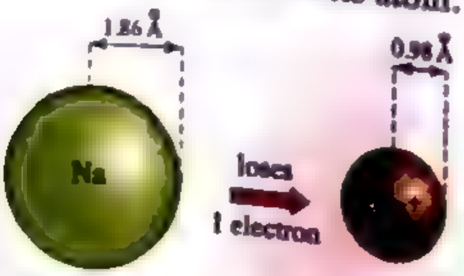


The relationship between nonmetals ra... and their negative ions

- The negative ion (the anion) radius is larger than its atomic radius, as the number of negative electrons in the anion is higher than the number of positive protons. So the repulsive forces between electrons inc... increasing the number of el... any increase in the effective charge leading to increasin...

Application

- The sodium metal tends to lose its valence electron during chemical reactions to form sodium ion of radius smaller than the radius of its atom.



Sodium atom $_{11}Na$

$1s^2, 2s^2, 2p^6, 3s^1$

11 protons

11 electrons

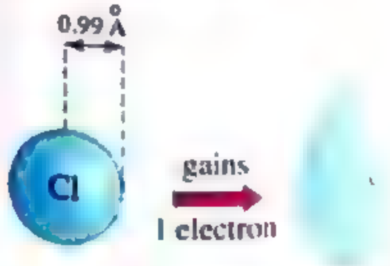
Sodium ion Na^+

$1s^2, 2s^2, 2p^6$

11 protons

10 electrons

- The chlorine nonmetal tend... an electron during chemica... form chloride ion of radius... the radius of its atom.



Chlorine atom $_{17}Cl$

$1s^2, 2s^2, 2p^6, 3s^2, 3p^5$

17 protons

Chlo...

$1s^2, 2s^2...$

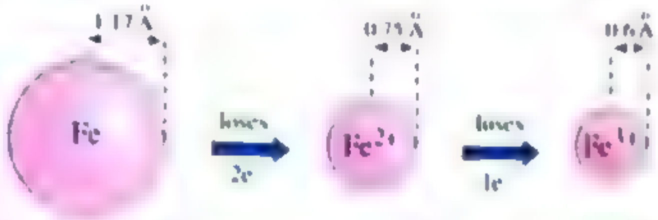
17 pro...

Worked Examples

1 **Arrange the following species descendingly according to the radius (Fe^{2+} / $_{26}Fe$ / Fe^{3+}), with explanation.**

Answer :

The atomic radius of iron atom ($_{26}Fe$) > The ionic radius of iron (II) ion Fe^{2+} > The ionic radius of iron (III) ion Fe^{3+}, because the atomic radii of metals are larger than the radii of their ions.
As the ionic radius of the positive ion decreases , when its charge increases.



Iron atom $_{26}Fe$	Iron (II) Fe^{2+}	Iron (III) Fe^{3+}
[Ar] , $4s^2$, $3d^6$	[Ar] , $4s^0$, $3d^6$	[Ar] , $4s^0$, $3d^5$
26 protons	26 protons	26 protons
26 electrons	24 electrons	23 electrons

Ionic radius of positive ion decreases as its charge increases

---

2 **The atom of the metal R is similar to its ion R^{2+} in ....**

(a) the size.
(b) the charge of the nucleus.
(c) the radius.
(d) the number of the electrons.

Idea of answering :

∵ The radius (and hence the size) of the positive ion is smaller than that of its atom.

∴ The choices (a) and (c) are excluded.

∵ The number of the electrons of the positive ion is lower than the number of the electrons of its atom.

∴ The choice (d) is excluded.

∵ The number of the protons inside the nucleus of the atom does not change during the formation of the ion.

∴ The charge of the nucleus remains the same.

Answer : The correct choice is (b)

Test Yourself

What happens on moving down the group of halogens from fluorine to iodine ?

(a) The ionic radius increases.
(b) The atomic number of the halogen decreases.
(c) The atomic radius decreases.
(d) The number of the valence electrons in the halogen atom increases.

Answer : The correct choice is ....

Worked Example

Arrange the opposite ions descendingly according to their radii.

$_{12}Mg^{2+}$ | $_{19}K^{+}$ | $_{33}As^{3-}$

Idea of answering :

It is clear from the electronic configurations of the atoms of these elements that 3 of them are located in the same period (the fourth).

Element	Electronic configuration	Period
$_{12}Mg$	[Ne], $3s^2$	The third
$_{19}K$	[Ar], $4s^1$	The fourth
$_{33}As$	[Ar], $4s^2, 3d^{10}, 4p^3$	The fourth
$_{35}Br$	[Ar], $4s^2, 3d^{10}, 4p^5$	The fourth

∵ Atomic radii of the elements of the same period decrease with increasing the atomic numbers.

∴ $_{19}K > _{33}As > _{35}Br$

∵ The radius of the positive ion is smaller than that of its atom, and the radius of the negative ion is larger than that of its atom.

∴ $_{33}As^{3-} > _{35}Br^{-} > _{19}K^{+}$

∵ The ionic radius of $_{12}Mg^{2+}$ is smaller than that of $_{11}Na^{+}$, as each of these elements is in the same period.

∵ The ionic radius of $_{11}Na^{+}$ is smaller than that of $_{19}K^{+}$, as these two elements are in the same group.

∴ $_{19}K^{+} > _{12}Mg^{2+}$

Answer :

The correct descending order of the radii of the ions is : $_{33}As^{3-}$ > $_{35}Br^{-}$ >

2 Ionization potential (Ionization energy)

If an amount of energy is supplied to an atom – when being in the gaseous st... may be excited and transferred to higher energy levels, but if a sufficient am... supplied, the most loosely bound electron will be completely removed, givin... **The minimum amount of this energy is called ionization potential.**

- ΔH of the ionization process has a positive sign, because the ionization ene... an absorbed energy.

$$\underset{[Ne],\,3s^1}{Na_{(g)}} + \text{Energy} \longrightarrow \underset{[Ne],\,3s^0}{Na^{+}_{(g)}} + e^{-} \quad , \Delta H = +\,496 \text{ kJ/mol}$$

- The atom of the same element has more than ionization energy as shown in the following :

First ionization potential	Second ionization potential	Third ionization potential
Is the amount of energy required to remove an electron which is most loosely bound to the nucleus in an isolated gaseous atom $M_{(g)}$ + Energy $\longrightarrow M^{+}_{(g)} + e^-$, $\Delta H = (+)$ This leads to the formation of an ion which carries one positive charge	Is the amount of energy required to remove an electron from a positive ion carries one positive charge $M^{+}_{(g)}$ + Energy $\longrightarrow M^{2+}_{(g)} + e^-$, $\Delta H = (+)$ This leads to the formation of an ion which carries two positive charges	Is the amount of energy required to remove an electron from a positive ion carries two positive charges $M^{2+}_{(g)}$ + Energy $\longrightarrow M^{3+}_{(g)} + e^-$, $\Delta H = (+)$ This leads to the formation of an ion which carries three positive charges
The first ionization potential < The second ionization potential < The third ionization potential		

Worked Example

In terms of the following equations :

(1) $Na_{(g)} \longrightarrow Na^{+}_{(g)} + e^-$ $\qquad \Delta H = w$

(2) $Na_{(g)} \longrightarrow Na^{2+}_{(g)} + 2e^-$ $\qquad \Delta H = x$

(3) $Na_{(s)} \longrightarrow Na_{(g)}$ $\qquad \Delta H = y$

(4) $Na_{(s)} \longrightarrow Na^{2+}_{(g)} + 2e^-$ $\qquad \Delta H = z$

Which of the following equations represents the second ionization potential of sodium ?

ⓐ Equation (2) × Equation (1).
ⓑ Equation (2) – Equation (1).
ⓒ Equation (3) – Equation (1).
ⓓ Equation (4) – Equation (3).

Idea of answering :

∵ The ionization potential indicates that the atom is in its gaseous state $Na_{(g)}$

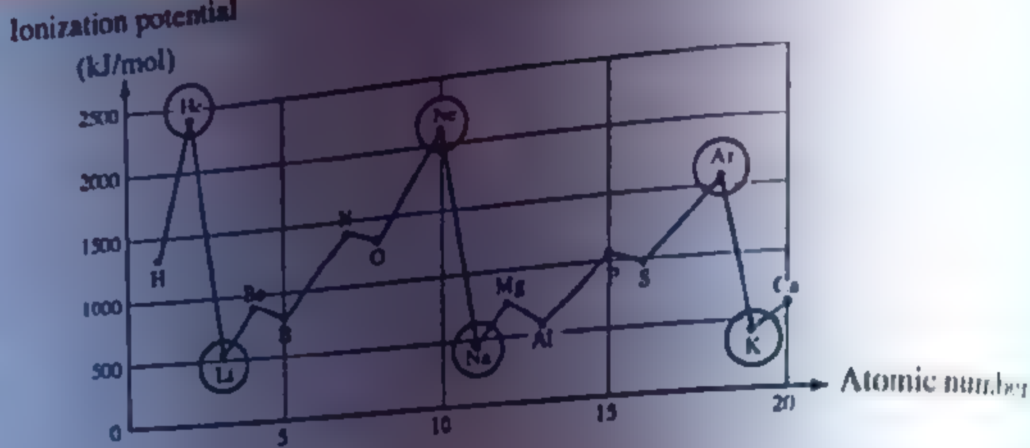
∴ The choices ⓒ and ⓓ are excluded.

∵ Equation (2) represents both the first and the second ionization potentials, while equation (1) represents the first ionization potential only.

∴ The equation which represents the second ionization potential only is the difference of subtracting equation (1) from equation (2).

Answer : The correct choice is ⓑ

Application 1 The first ionization potential of noble gases and alkali ...



- The first ionization potential of **noble gases is very high, due to the stability** of their electronic configuration and it is difficult to remove an electron from a completely f...

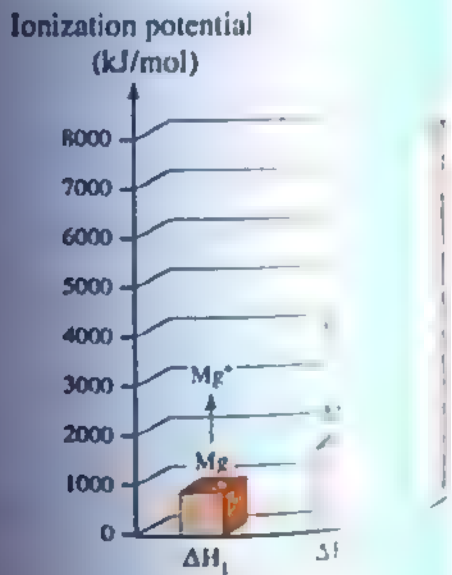
  * Examples : $_{10}Ne$: [He] , $2s^2$, $2p^6$ $_{18}Ar$: [Ne] , $3s^2$, $3p^6$

- The first ionization energy of **alkali metals is lower than that of all elements, due to the ease of losing** of the valence electron.

  * Examples : $_{11}Na$: [Ne] , $3s^1$ $_{19}K$: [Ar] , $4s^1$

Application 2 The ionization potentials of magnesium :

The opposite figure expresses the ionization potentials of magnesium, it's clear that :



- The second ionization energy of magnesium is higher than the first one, **due to increasing** the effective nuclear charge (Z_{eff}).
- The third ionization potential of magnesium is **much higher** than that of its first and second ones, **because** it results in the breaking up of a completely filled energy level.

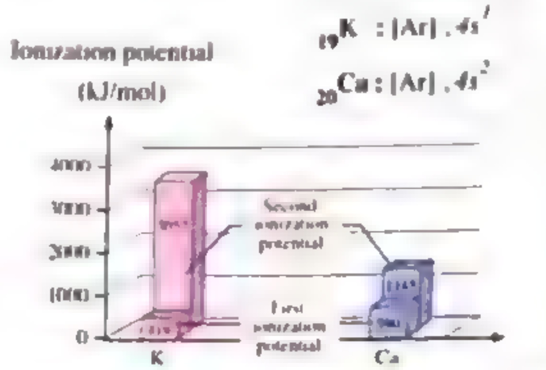
$$\underset{1s^2,2s^2,2p^6,3s^2}{Mg_{(g)}} \longrightarrow \underset{1s^2,2s^2,2p^6,3s^1}{Mg^+_{(g)}} + e^- \quad , \quad \Delta H_1 = +738 \text{ kJ/mol}$$

$$\underset{1s^2,2s^2,2p^6,3s^1}{Mg^+_{(g)}} \longrightarrow \underset{1s^2,2s^2,2p^6}{Mg^{2+}_{(g)}} + e^- \quad , \quad \Delta H_2 = +1450 \text{ kJ/mol}$$

$$\underset{1s^2,2s^2,2p^6}{Mg^{2+}_{(g)}} \longrightarrow \underset{1s^2,2s^2,2p^5}{Mg^{3+}_{(g)}} + e^- \quad , \quad \Delta H_3 = +7730 \text{ kJ/mol}$$

Notice that

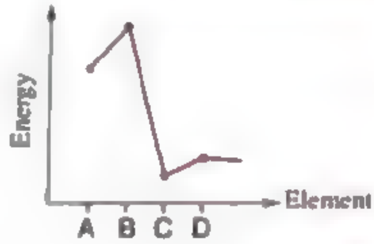
The first ionization potential of potassium $_{19}K$ is lower than that of calcium $_{20}Ca$, due to losing the valence electron easily, while the second ionization potential of potassium is much higher than that of calcium because it results in breaking a completely filled shell.



Ionization potentials of potassium and calcium

Test Yourself

The opposite figure represents the second ionization potentials of some elements.
Which of them represents $_3Li$?



ⓐ A ⓑ B
ⓒ C ⓓ D

Idea of answering :

The electronic configuration of $_3Li$ is ....

∵ The second ionization potential of lithium results in the breakage of a completely filled ....

∴ Its second ionization potential is .... compared to those of the other elements.

Answer : The correct choice is ....

Worked Example

The opposite table shows the first three ionization potentials E_1 , E_2 and E_3 of an element.
What is the most stable oxidation state of this element ?

E_1	E_2	E_3
7 eV	12.5 eV	42.5 eV

ⓐ +1 ⓑ +2 ⓒ +3 ⓓ +4

Idea of answering :

∵ The third ionization potential of this element is much higher than its second ionization potential.

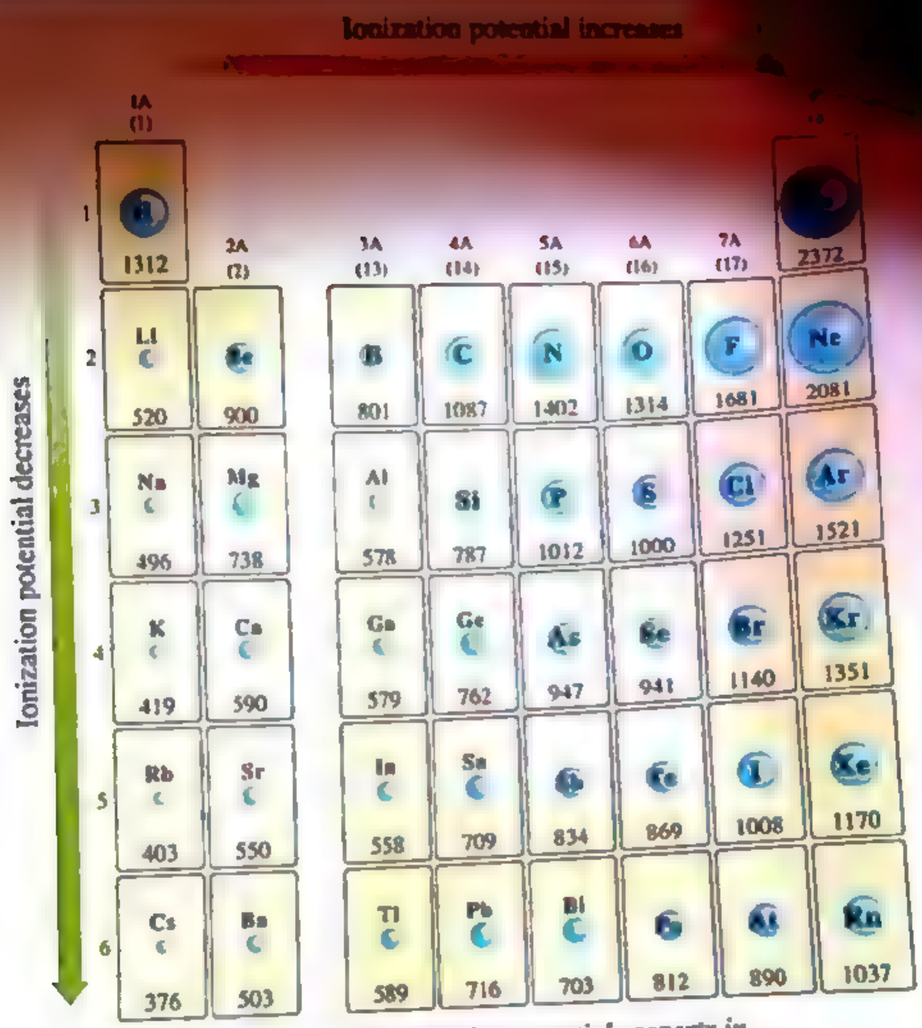
∴ It results in the breakage of a completely filled (a stable) energy level.

∴ The element is divalent (belongs to group 2A).

∴ Its most stable oxidation state is +2

Answer : The correct choice is ⓑ

The graduation of ionization potential in the periodic



Graduation of the ionization potential property in the elements of s and p-blocks "The values estimated in kJ/mol for illustration"

In the same period	In the same group
The first ionization potential increases as we move from left to right	The first ionization energy decre as we go down the group

This is due to

The increase of the effective nuclear charge and the decrease of the atomic radius, which would lead to increasing the attraction of the nucleus to the valence electrons, so they need higher energy to be separated from the nucleus	• The increase in the number of energy which are completely filled with ele which increases the atomic radius. • The decrease of attraction of the nu to the valence electrons, so the energy required to remove the valence electrons decreas .

i.e the ionization potential is **inversely proportional** to the atomic radius

Notes

❶ The ionization potential of phosphorus $_{15}P$ is higher than the ionization potential of sulphur $_{16}S$, although phosphorus precedes sulphur in the same period.

$_{15}P$: [Ne] , $3s^2$, $3p^3$ [↑][↑][↑] $\xrightarrow{-e^-}$ $_{15}P^+$: [Ne] , $3s^2$, $3p^2$ [↑][↑][ ]

$_{16}S$: [Ne] , $3s^2$, $3p^4$ [↑↓][↑][↑] $\xrightarrow{-e^-}$ $_{16}S^+$: [Ne] , $3s^2$, $3p^3$ [↑][↑][↑]

Because the atom becomes more stable when the $3p$ sublevel is half filled with electrons as in phosphorus atom and removing an electron from it will decrease its stability.

❷ The ionization potential of aluminum $_{13}Al$ is lower than that of magnesium $_{12}Mg$, although aluminum comes next magnesium in the same period.

$_{12}Mg$: [Ne] , $3s^2$ $_{13}Al$: [Ne] , $3s^2$, $3p^1$

Because the atom becomes more stable when the $3s$ sublevel is completely filled with electrons as in magnesium atom and removing an electron from it will decrease its stability.

Worked Examples

1 Which of the following choices shows two elements having almost the same ionization potential ?

ⓐ $_{13}Al$, $_{31}Ga$

ⓑ $_{38}Sr$, $_{31}Ga$

ⓒ $_{31}Ga$, $_{87}Fr$

ⓓ $_{87}Fr$, $_{13}Al$

Idea of answering :

The following table exhibits the electronic configurations of the atoms of the mentioned elements, and their locations in the periodic table :

Element	Electronic configuration of the element atom	Period number	Group number
$_{13}Al$	[Ne] , $3s^2$, $3p^1$	3	3A
$_{31}Ga$	[Ar] , $4s^2$, $3d^{10}$, $4p^1$	4	3A
$_{38}Sr$	[Kr] , $5s^2$	5	2A
$_{87}Fr$	[Rn] , $7s^1$	7	1A

∵ $_{13}Al$ and $_{13}Ga$ are closest to each other in terms of the number of their group and the numbers of their periods as well.

∴ Their ionization potentials are almost the same.

Element	Ionizatoion potential (kJ/mol)
Al	578
Ga	579
Sr	550
Fr	380

"For illustration only"

Answer : The correct choice is (a)

2 The following graphical figures show the first eight ionization potentials of two elements in the third period in the modern periodic table :

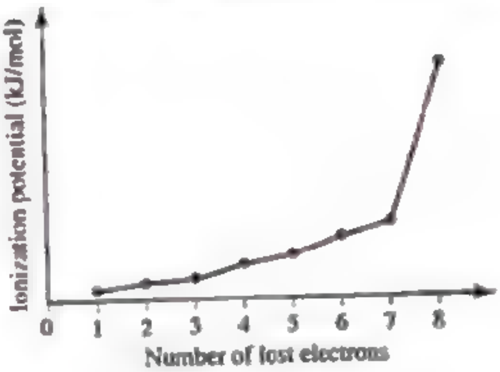


Figure (1)

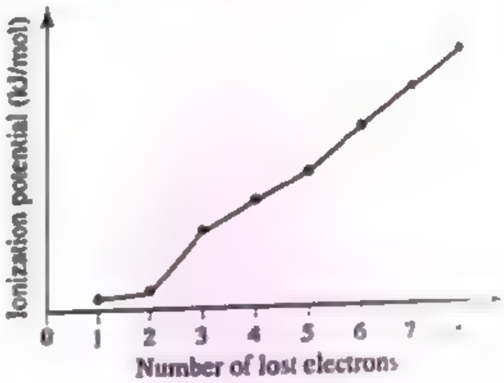


Figure (2)

What is the formula of the ionic compound which is produced from the combinat of these two elements ?

(a) $MgCl_2$ (b) $CaBr_2$ (c) Na_2S (d) K_2O

Idea of answering :

* In figure (1), there is a significant elevation in the 8th ionization potential of this compared to the lower ionization potentials, it means that removing 8 electrons fr the atom of this element will lead to breaking a completely filled energy level.
  - ∴ The valence shell of this element contains 7 electrons, **i.e.** this element is locate in group (7A) (the halogens), which means that it can be chlorine Cl or bromin
  - ∴ The choices (c) and (d) are excluded.
* In figure (2), it is clear that the significant elevation appears in the 3rd ionization p of this element.
  - ∴ The valence shell of this element contains 2 electrons, **i.e.** this element is located group (2A), so it can be magnesium Mg or calcium Ca, but it is given in the data the question that the element is located in the third period.
  - ∵ Mg is in the third period, while Ca is in the fourth.
  - ∴ The choice (b) is excluded.

Answer : The correct choice is (a)

- We have mentioned that the removal of an electron from the atom will convert it into a cation, which requires an amount of energy named by the first ionization potential. On the other hand, if the atom gained an extra electron, it will be converted into a negative ion. This is associated with releasing an amount of energy named by *electron affinity* which is *the amount of energy released when an extra electron is added to a neutral gaseous atom.*

$$X_{(g)} + e^- \longrightarrow X^-_{(g)} + \text{Energy} \quad , \quad \Delta H = (-)$$

- The magnitude of the electron affinity is high when the added electron makes the sublevel, half filled or completely filled, as in both cases it helps in the stability of the atom.

Test Yourself

Which of the following equations represents the electron affinity of bromine ?

ⓐ $Br_{(g)} \longrightarrow Br^+_{(g)} + e^-$

ⓑ $Br_{(g)} + e^- \longrightarrow Br^-_{(g)}$

ⓒ $Br_{2(g)} + e^- \longrightarrow 2Br^-_{(g)}$

ⓓ $Br^+_{(g)} + e^- \longrightarrow Br_{(g)}$

Answer : The correct choice is ....

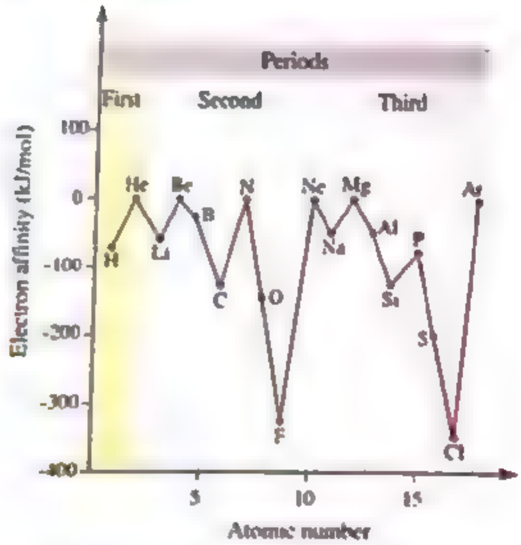
The graduation of electron affinity in the periodic table

Electron affinity increases

Electron affinity decreases

	1A	2A	3A	4A	5A	6A	7A	0
1	H -73							He >0
2	Li -60	Be >0	B -27	C -122	N >0	O -141	F -328	Ne >0
3	Na -53	Mg >0	Al -43	Si -134	P -72	S -200	Cl -349	Ar >0

The values of the electron affinities of the first 18 elements in the periodic table "in kJ/mol"



In the same period	In the same group
The electron affinity increases as we move from left to right	The electron affinity decreases as we go down the group

This is due to

The increase of the atomic number leads to the decrease in the atomic radius (and hence the atomic size), which facilitates for the nucleus to attract a new electron	The increase of the atomic number leads to the increase in the atomic radius (and hence the atomic size), which hinders the nucleus to attract a new electron

* The electron affinity values for beryllium $_4Be$, nitrogen $_7N$ and neon $_{10}Ne$ are cl...

$_4Be : 1s^2 , 2s^2$, $_7N : 1s^2 , 2s^2 , 2p^3$, $_{10}Ne : 1s^2 , 2s^2 , 2p^6$

because the atom will be more stable when the sublevel :

- $2s$ is completely filled as in case of beryllium atom $_4Be$
- $2p$ is half filled as in case of nitrogen atom $_7N$
- $2p$ is completely filled as in case of neon atom $_{10}Ne$

and the addition of an electron to any atom of them will decrease its stability.

* The electron affinity of chlorine (– 349 kJ/mol) is greater than the electron af...
fluorine (– 328 kJ/mol), although chlorine follows fluorine in the same group.

because fluorine atom is smaller in size as it has smaller radius than chlorine at... any new electron will suffer a strong repulsive force with the nine electrons alrea... around the fluorine nucleus which decreases **the released energy** due to consum... of this energy to overcome this repulsive force.

Test Yourself

The relation between the electron affinity of sulphur and that of oxygen rese... relation between the electron affinity of chlorine and that of fluorine.
Which of these choices represents the correct descending graduation in elect... in nitrogen, oxygen and sulphur ?

(a) S > O > N

(b) O > S > N

(c) N > O > S

(d) S > N > O

Answer : The correct choice is ....

Worked Example

Based on the equation and the table :

$K_{(g)} + Cl_{(g)} \longrightarrow K^+_{(g)} + Cl^-_{(g)}$ $\Delta H = ?$

What is the value of ΔH ?

(a) 1303 kJ/mol (b) 1207 kJ/mol

(c) 767 kJ/mol (d) 69 kJ/mol

	Ionization potential	Electron affinity
Potassium	+418 kJ/mol	– 48 kJ/mol
Chlorine	+1255 kJ/mol	–349 kJ/mol

Idea of answering :

- $K_{(g)} \longrightarrow K^+_{(g)} + e^-$ $\Delta H = +418$ kJ/mol
- $Cl_{(g)} + e^- \longrightarrow Cl^-_{(g)}$ $\Delta H = -349$ kJ/mol

By addition

$K_{(g)} + Cl_{(g)} \longrightarrow K^+_{(g)} + Cl^-_{(g)}$ $\Delta H = (+418) + (-349) = 69$ kJ/mol

Answer : The correct choice is (d)

---

4 Electronegativity

- When two atoms of two different elements combine together, the ability of one atom of them to attract the electrons of the chemical bond differs from that of the other atom, this attraction force is known as

electronegativity *which is the ability of an atom to attract the electrons of the chemical bond to itself.*

The electron affinity differs from the electronegativity, where the electron affinity is **an energy term** which refers to an atom in its single state, while the electronegativity of the elements is represented by **relative values** and it refers to a combined atom.

- The increase of the relative values of the electronegativity means the increase in the ability of the element atom to attract the electrons of the chemical bond.
- The difference in electronegativity between elements plays a very important role in determining the nature of the bond formed between them

(as will be discussed later in chapter 3 - second term).

The graduation of electronegativity in the periodic table

Electronegativity increases →

Electronegativity decreases ↓

Period	1A	2A	3A	4A	5A	6A	7A
1	H 2.1						
2	Li 1.0	Be 1.5	B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
3	Na 0.9	Mg 1.2	Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
4	K 0.8	Ca 1.0	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
5	Rb 0.8	Sr 1.0	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
6	Cs 0.7	Ba 0.9	Tl 1.8	Pb 1.9	Bi 1.9	Po 2.0	At 2.2

In the same period	In the same group
The electronegativity increases as we move from left to right	The electronegativity decreases as we go down the group

This is due to

The increase of the atomic number leading to the decrease of atomic radius, so the ability of the atom to attract the electrons of the bond increases	The increase of the atomic number leading to the increase of atomic radius, so the ability of the atom to attract the electrons of the bond decreases

General conclusion :

- The atoms of nonmetals of group 7A (halogens) are the greatest in the electronegativity, while the atoms of the alkali metals of group 1A are the lowest in the electronegativity.
- Fluorine (F) is the most electronegative element, while cesium (Cs) is the lowest electronegative element.

Worked Example

The opposite figure shows a section in the modern periodic table.
Which of the following represents the electronegativities of these elements ?

		$_{33}$As		
$_{49}$In	$_{50}$Sn	$_{51}$Sb	$_{52}$Te	$_{53}$I
		$_{83}$Bi		

Choices	The highest electronegative element	The lowest electronegative element
(a)	As	Bi
(b)	I	In
(c)	I	Bi
(d)	Te	Sn

Idea of answering :

- The opposite table exhibits the electronic configurations of the atoms of these elements, and it shows that all these elements are of p-block elements.

Element	Electronic configuration of the element atom
$_{33}$As	[Ar] , $4s^2, 3d^{10}, 4p^3$
$_{83}$Bi	[Xe] , $6s^2, 5d^{10}, 4f^{14}, 6p^3$
$_{53}$I	[Kr] , $5s^2, 4d^{10}, 5p^5$
$_{49}$In	[Kr] , $5s^2, 4d^{10}, 5p^1$
$_{52}$Te	[Kr] , $5s^2, 4d^{10}, 5p^4$
$_{50}$Sn	[Kr] , $5s^2, 4d^{10}, 5p^2$

∵ Sublevel *p* in the atom of each of the two elements As and Bi contains the same number of the unpaired electrons.

∴ The difference in the electronegativity between these two elements is insignificant.

∴ The choice (a) is excluded.

∵ Sublevel *p* in the atom of In element contains only one electron, while in the atom of I element, it contains 5 electrons.

∴ The electronegativity of iodine I will be the highest, and that of indium In will be the lowest.

Answer : The correct choice is (b)

Questions ? 2 Lesson Two

Ready

Answer then ...

... for each of the following sentences :

(1) ... in the periodic table are those of ....

group 1B

halogens group.

... radius is ......

(3) The opposite table represents the electronic configurations of an atom in the ground state and of its ion.

Electronic configuration of the atom	$1s^2, 2s^2, 2p^6$
Electronic configuration of the ion	$1s^2, 2s^2, 2p^6$

Which of the following conversions represents this atom ?

a. $B \longrightarrow B^{3+}$ b. $Al \longrightarrow Al^{3+}$

c. $N \longrightarrow N^{3-}$ d. $P \longrightarrow P^{3-}$

(4) The element with the smallest atomic radius among the elements of the same group is that which has ......

a. the highest number of neutrons inside the nucleus.

b. the lowest number of protons inside the nucleus.

c. the lowest electronegativity.

d. the highest number of electrons around the nucleus.

(5) Which of the fo... of calcium ?

a. $Ca_{(g)}$ + Energ...

b. $Ca^{+}_{(g)}$ + Ener...

c. $Ca^{-}_{(g)} + e^{-}$ ...

d. $Ca^{+}_{(g)} + e^{-}$ ...

(6) Which of the ... the other elem...

a. Lithium.

Sodium.

(7) Increasing th... leads to ......

a. the difficul...

b. the ease o...

c. increasing...

d. increasing...

(8) Halogens ar...

a. high elec...

c. high ioni...

(9) What is the ... the atomic ...

a. Ionizatio...

c. Electron...

(10) In the thi...

a. the ato...

b. the ato...

c. the ele...

d. the ato...

(5) Which of the following equations represents the second ionization potential of calcium ?

a. $Ca_{(g)} + \text{Energy} \longrightarrow Ca^{+}_{(g)} + e^{-}$

b. $Ca^{+}_{(g)} + \text{Energy} \longrightarrow Ca^{2+}_{(g)} + e^{-}$

c. $Ca^{-}_{(g)} + e^{-} \longrightarrow Ca^{2-}_{(g)} + \text{Energy}$

d. $Ca^{+}_{(g)} + e^{-} \longrightarrow Ca_{(g)} + \text{Energy}$

(6) Which of the following elements has the highest electronegativity compared to the other elements in the periodic table ?

a. Lithium.

b. Fluorine.

c. Sodium.

d. Cesium.

(7) Increasing the distance between the last electron and the nucleus in an atom leads to ....

a. the difficulty of sharing this electron.

b. the ease of losing this electron.

c. increasing the attraction between the electron and the nucleus.

d. increasing the electronegativity.

(8) Halogens are characterized by all the following, except ....

a. high electronegativity.

b. small atomic radius.

c. high ionization energy.

d. small electron affinity.

(9) What is the property which decreases in the same period with increasing the atomic number ?

a. Ionization potential.

b. Electron affinity.

c. Electronegativity.

d. Atomic radius.

(10) In the third period, on moving from sodium to argon, both ....

a. the atomic number and the atomic size increase.

b. the atomic number and the electronegativity increase.

c. the electronegativity and the atomic size increase.

d. the atomic size and the ionization potential increase.

Multiple choice questions

The atomic radius

If the length of the bond in A_2 molecule equals 1.98 Å, and its length in AB molecule equals 1.29 Å

What is the bond length in B_2 molecule ?

(a) 0.69 Å
(b) 3.27 Å
(c) 1.32 Å
(d) 0.6 Å

Magnesium ion $^{24}_{12}Mg^{2+}$ contains ..

(a) 12 protons, 10 electrons.
(b) 24 protons, 26 electrons.
(c) 12 protons, 13 electrons.
(d) 24 protons, 14 electrons.

The highest number of the unpaired electrons is in .... (Atomic number of ...

(a) Fe
(b) Fe^{4+}
(c) Fe^{2+}
(d) Fe^{3+}

The effective nuclear charge is the highest in ....

(a) $_{22}Ti$
(b) $_{26}Fe$
(c) $_{22}Ti^{3+}$
(d) $_{26}Fe^{3+}$

The atomic radius of fluorine $_9F$ is smaller than that of carbon $_6C$, because

(a) the quantum numbers of the last electron of F atom are smaller than those of C
(b) the repulsion between the electrons of the completely filled p orbitals is stronger than that between the electrons of the half filled p orbitals.
(c) the effective nuclear charge of fluorine is larger than that of carbon.
(d) fluorine is heavier than carbon.

6 **Which of the following relations is correct for the elements of the same period ?**

ⓐ The radius of M^+ ion > That of X^- ion.

ⓑ The radius of X^- ion > That of X atom.

ⓒ The radius of M^+ ion = That of X^- ion.

ⓓ The radius of M^+ ion > That of M atom.

7 **What does happen when a strontium $_{38}Sr$ atom is converted to its ion ?**

Choices	A cation is formed with a charge equals	The ionic radius compared to that of the atom
ⓐ	+1	Smaller
ⓑ	+1	Larger
ⓒ	+2	Smaller
ⓓ	+2	Larger

8 **Which of the ... ions has the largest radius ?**

ⓐ F^-

ⓑ Li^+

ⓒ I^-

ⓓ Rb^+

9 **If the atomic radius of rubidium is 253 Pm**

What is its ionic radius (rounded to the nearest integer) ?

ⓐ 148 pm

ⓑ 253 pm

ⓒ 275 pm

ⓓ 300 pm

10 **Which of the following is the correct ascending graduation of the ionic radii of these elements ?**

ⓐ $Al^{3+} < Na^+ < F^- < N^{3-}$

ⓑ $Na^+ < F^- < N^{3-} < Al^{3+}$

ⓒ $N^{3-} < F^- < Na^+ < Al^{3+}$

ⓓ $Na^+ < F^- < Al^{3+} < N^{3-}$

11 **The element whose electronic configuration ends with ns^2, np^4 , ...**

ⓐ its ion has radius smaller than that of its atom.

ⓑ its ion has radius larger than that of its atom.

ⓒ its atom has radius smaller than that of its positive ion.

ⓓ its atom has radius smaller than that of the atom of the element which precedes it in the same group.

12 Which of the following choices is more accurate in representing th[e ratio of] the atomic radius of sodium to its ionic radius (both estimated in pic[ometers]) ?

(a) $\frac{138}{235}$

(b) $\frac{190}{102}$

(c) $\frac{144}{143}$

(d) $\frac{58}{157}$

13 If the four quantum numbers of the last electron in the valence s[hell] of the element (X) are : $(4, 3, 0, +\frac{1}{2})$ respectively.

What is the atomic number of the element (Y) which has the biggest a[tomic radius in] the same period of the element (X) ?

(a) 19

(b) 37

(c) 55

(d) 71

Ionization potential

14 Which of the following elements has the lowest second ionization potential ?

(a) $_{16}S$

(b) $_{11}Na$

(c) $_{7}N$

(d) [illegible]

15 In the equation : $X_{(g)} + \text{Energy} \longrightarrow X^{+}_{(g)} + e^{-}$

The absorbed energy is

(a) less than the difference in energy between the outermost energy level and the ...

(b) equal to the difference in energy between the outermost energy level and the ...

(c) larger than the difference in energy between the outermost energy level and the ...

(d) half the difference in energy between the outermost energy level and the ...

16 This table shows the first three ionization potentials of magnesium element.

What is the amount of energy required to obtain magnesium ion which has the same electron configuration of the nearest noble gas ?

First ionization potential	+7[illegible]
Second ionization potential	+145[illegible]
Third ionization potential	+77[illegible]

(a) +1451 kJ/mol

(b) +2189 kJ/mol

(c) +9184 kJ/mol

(d) +9922 kJ/mol

17 In the opposite table.
How can the change in the second ionization potential be explained ?

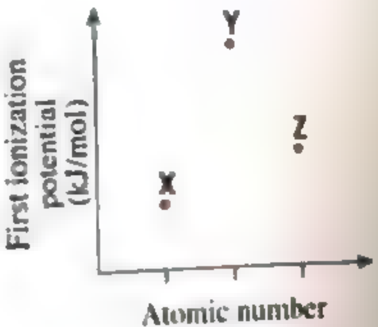
Element	Na	Mg
First ionization potential (kJ/mol)	+496	+738
Second ionization potential (kJ/mol)	+4558	+1451

(a) The first and second ionization potentials are from two different energy levels in sodium, while in magnesium they are from the same energy level.
(b) Electronegativity of sodium is lower than that of magnesium.
(c) Losing an electron from magnesium atom causes the other electron to repel with magnesium cation.
(d) Losing an electron from sodium atom causes the half filling of $2p$ sublevel, while it requires losing two electrons from magnesium atom to cause $2p$ sublevel to be half filled.

18 The difference between the two values of first and second ionization potentials is very large in case of the atoms of ....
(a) neon $_{10}Ne$
(b) potassium $_{19}K$
(c) magnesium $_{12}Mg$
(d) aluminum $_{13}Al$

19 If the ionization potential of hydrogen $H_{(g)}$ equals +1312 kJ/mol, it is most likely that the second ionization potential of helium $He_{(g)}$ equals ....
(a) +5248 kJ/mol
(b) +1312 kJ/mol
(c) +656 kJ/mol
(d) +328 kJ/mol

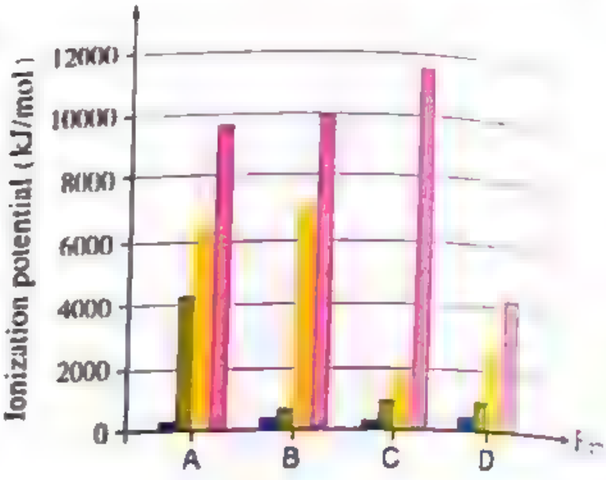
20 The opposite figure represents the first ionization potentials of three elements (X) , (Y) and (Z), which are successive elements in the periodic table. The element (X) can be ....



(a) carbon $_6C$
(b) fluorine $_9F$
(c) oxygen $_8O$
(d) nitrogen $_7N$

21 The opposite graphical figure represents the first four ionization potentials of 4 elements (A), (B), (C) and (D).

What is the letter of the element which represents aluminum ?



ⓐ (A). ⓑ (B).

ⓒ (C). ⓓ (D).

22 Which of the following equations is incorrect ?

ⓐ $Na + e^- \longrightarrow Na^+ + Energy$

ⓑ $Mg + Energy \longrightarrow Mg^{2+} + 2e^-$

ⓒ $Na^+ + e^- \longrightarrow Na + Energy$

ⓓ $H_2 + Energy \longrightarrow 2H^+ + 2e^-$

23 The first and the second ionization potentials of the element (X) which is located in group (2A) in the modern periodic table are represented as follow

(1) $X_{(g)} \longrightarrow X^+_{(g)} + e^-$, $\Delta H = +589.8$ kJ/mol

(2) $X^+_{(g)} \longrightarrow X^{++}_{(g)} + e^-$, $\Delta H = +1145.4$ kJ/mol

What is the probable value of the third ionization potential of (X) ?

ⓐ +798.6 kJ/mol ⓑ +1500.43 kJ/mol

ⓒ +2000.82 kJ/mol ⓓ +4912.4 kJ/mol

24 The following table represents the first five ionization potentials of the element (X) in kJ/mol :

Ionization potential	First	Second	Third	Fourth	Fifth
Value of ionization potential (kJ/mol)	+738	+1450	+7733	+10543	+13630

What is the chemical formula of the compound which is produced from the combination of the element (X) with chlorine ?

ⓐ XCl ⓑ XCl_2

ⓒ XCl_3 ⓓ X_2Cl_3

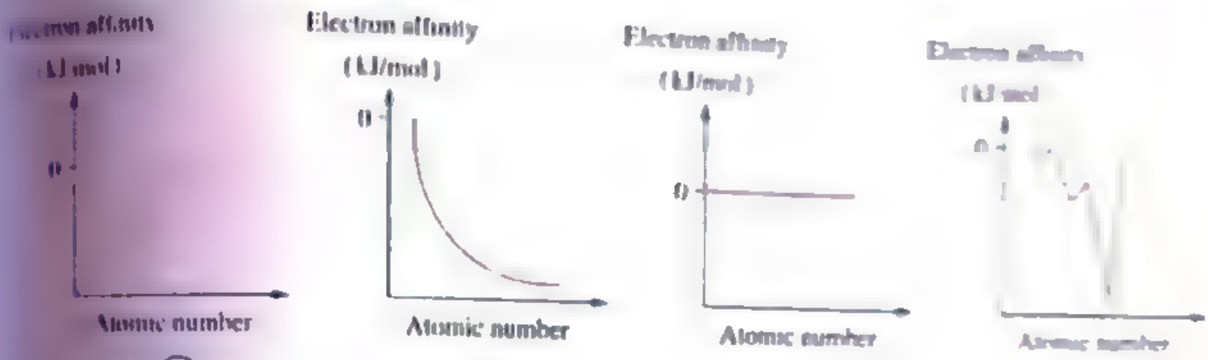
25 Which of the following has a higher value in lithium Li than in potassium K ?

ⓐ First ionization potential. ⓑ Atomic radius.

ⓒ Atomic number. ⓓ Ionic radius.

Electron affinity

Which of the following graphical figures represents the relation between the electron affinity and the atomic number in the elements of the third period in the periodic table ?



(a) (b) (c) (d)

Which of the following choices represents the proper graduation in the electron affinity ?

(a) $_{17}Cl > _{9}F > _{16}S > _{8}O$
(b) $_{9}F > _{8}O > _{16}S > _{17}Cl$
(c) $_{9}F > _{17}Cl > _{16}S > _{8}O$
(d) $_{17}Cl > _{16}S > _{8}O > _{9}F$

Chlorine forms a negative ion unlike sodium, because ....

(a) chlorine is a gas, while sodium is a solid.
(b) the atomic size of chlorine is larger than that of sodium.
(c) the electron affinity of chlorine is larger than that of sodium.
(d) chlorine is more metallic than sodium.

Which of the following represents the proper graduation ?

(a) Electron affinity ($_{17}Cl < _{8}O < _{9}F$).
(b) Ionization potential ($_{19}K < _{12}Mg < _{13}Al$)
(c) Atomic radius ($_{33}As < _{15}P < _{14}Si$).
(d) Ionic radius ($_{12}Mg^{2+} < _{20}Ca^{2+} < _{19}K^{+}$).

Electronegativity

In the same period, the element which gains electrons during the chemical reactions is characterized by ....

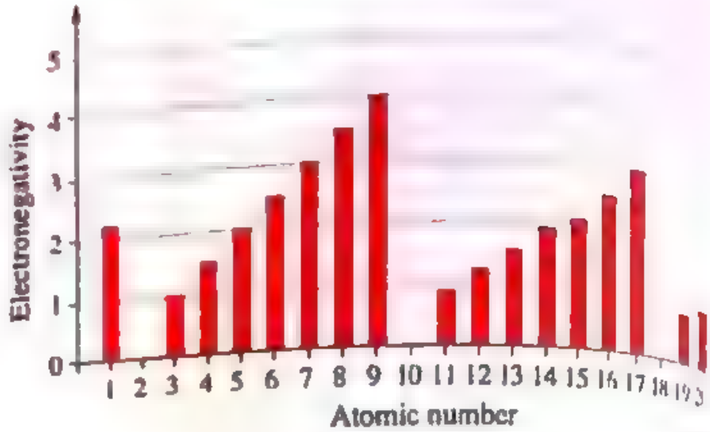
(a) lower electron affinity.
(b) higher electronegativity.
(c) lower first ionization potential.
(d) larger atomic radius.

Which of the following choices represents the proper graduation in electronegativity ?

(a) $_{6}C < _{7}N < _{14}Si < _{15}P$
(b) $_{14}Si < _{15}P < _{6}C < _{7}N$
(c) $_{7}N < _{6}C < _{15}P < _{14}Si$
(d) $_{6}C < _{14}Si < _{7}N < _{15}P$

32 In the opposite graph :

Which of the following elements is characterized by the highest ability to attract the electrons ?



ⓐ $_{5}B$

ⓑ $_{8}O$

ⓒ $_{13}Al$

ⓓ $_{16}S$

33 The following table shows the values of the atomic radii of four elements located in the same group in the periodic table (estimated in angstroms) :

Element	A	B	C	D
Atomic radius (Å)	1.9	2.43	1.67	2.65

Which of the following choices is correct ?

ⓐ The electronegativity of (A) is lower than that of (B).

ⓑ The electronegativity of (D) is higher than that of (C).

ⓒ The electron affinity of (C) is lower than that of (A).

ⓓ The ionization potential of (B) is higher than that of (D).

Essay questions

34 If you know that :

- (O – H) bond length in water molecule = 0.96 Å
- The bond length in oxygen molecule (O_2) = 1.32 Å

Calculate the covalent radius of hydrogen atom.

35 If you know that :

- The atomic radius of chlorine = 0.99 Å
- The bond length in ammonia molecule = 1 Å
- The bond length in hydrogen chloride molecule = 1.29 Å

Calculate which is longer, the bond in hydrogen molecule or the bond in nitrogen mole

36 In the following table, calculate - with giving reason - the bond length in each of

Atom or ion	H^-	H	Na	Na^+	Cl	Cl^-
Radius (Å)	1.54	0.3	1.86	0.98	0.99	1.81

(1) The formula unit of sodium chloride.

(2) Hydrogen chloride molecule.

37 Arrange the following elements descendingly, with giving the reason .

(1) $_{17}Cl$, $_{12}Mg$, $_{20}Ca$ "According to the radius".

(2) I_2 , Br_2 , F_2 , Cl_2 "According to the bond length in the molecule".

38 Choose the number(s) of the statement(s) which illustrate(s) the difference between phosphide ion and phosphorus atom $_{15}P$:

(1) : The atomic radius of phosphorus is larger than the ionic radius of phosphide.

(2) : Phosphide ion contains higher number of electrons than in phosphorus.

(3) : Numbers of energy levels which are occupied by electrons in both of them are equal.

39 The opposite table shows the atomic and ionic radii of sulphur and calcium :

Element	Radius (nm)
$_{16}S$	0.104
S^{2-}	0.184
$_{20}Ca$	0.197
Ca^{2+}	0.099

(1) Why is sulphide ionic radius larger than the atomic radius of sulphur ?

(2) Why is the radius of S^{2-} larger than that of Ca^{2+} despite the similarity in their electronic configuration ?

40 Write the electronic configuration (according to Aufbau principle) of the element which is located in the third period in the modern periodic table, and the difference between its fifth and sixth ionization potentials is very large.

41 In the equation : $Y^+_{(g)} + \text{Energy} \longrightarrow Y^{++}_{(g)} + e^-$

(1) What does the energy represent in the previous equation ?

(2) Which is larger in radius, Y^+ or Y^{++} ? Why ?

42 Write the symbolic equation which represents the third ionization potential of titanium (Ti).

In the light of your studying for :

- Radius.
- Electron affinity.
- Ionization potential.
- Electronegativity.

What are the values required to calculate the change in energy of the reaction

$$Na_{(g)} + Cl_{(g)} \longrightarrow Na^+_{(g)} + Cl^-_{(g)}$$

Element (M) may have more than one ionization potential, while it has one value of the electron affinity, explain this statement.

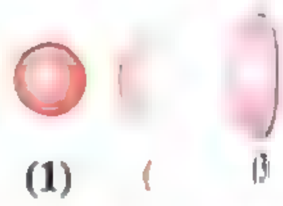
In the two compounds of chromium CrO , Cr_2O_3 :

(1) What is the number of electrons in chromium ion in each of the two compounds ?

"Knowing that the atomic number of chromium is 24".

(2) In which formula unit the (Cr – O) bond length is longer, CrO or Cr_2O_3 ? Give rea...

The opposite figures represent the relative sizes of each of $_{35}Br$, Br^- and $_9F$ "in no particular order". Choose, with explaining your answer, the proper figure number for each atom or ion.



The following figure represents the first four periods in the periodic tab...

"The letters in the table are not the real symbols of the elements"

Choose the symbol(s) of the element which :

(1) Has the largest radius in the third period.

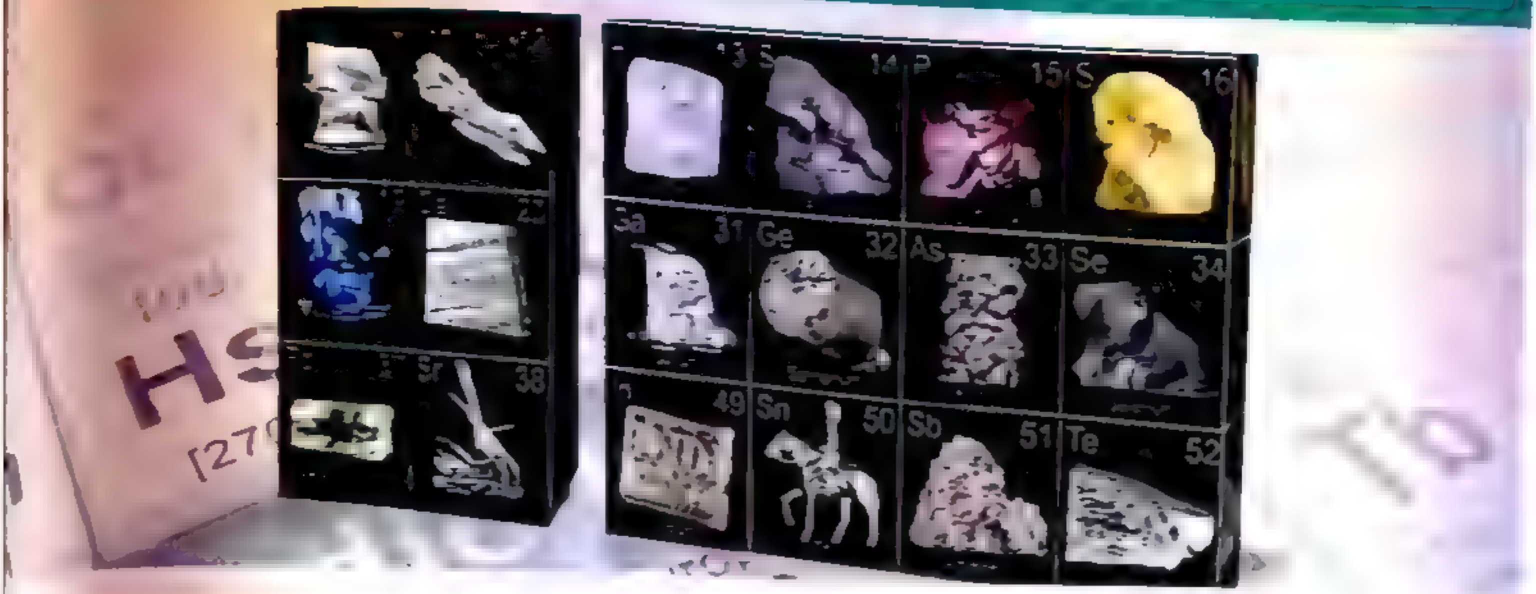
(2) Has the lowest ionization potential in group 2 A

(3) Has the highest electronegativity.

(4) Forms compounds with great difficulty.

(5) Has the highest first ionization potential.

(6) Has an electron affinity higher than (G).



5 Metallic and nonmetallic property

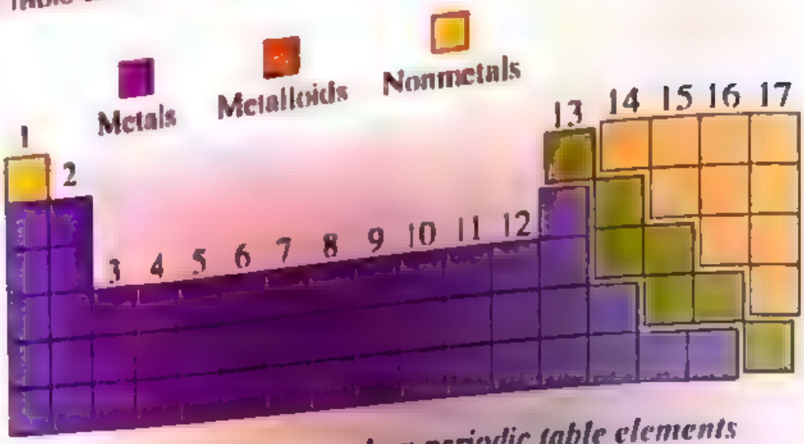
Berzelius

- At the beginning of the nineteenth century, "Berzelius" was the first scientist who classified elements into two main groups (metals and nonmetals), according to their physical properties. Indeed that was before knowing anything about atomic structure.

- This is an old classification which is still currently in use, although there are no boundaries between their properties.

- With the development of our concept of the electronic structure of atoms, we can differentiate between metals and nonmetals. In addition to, a third group of elements known as metalloids.

A Metals. **B** Nonmetals. **C** Metalloids.



Classification of the modern periodic table elements into metals, nonmetals and metalloids

A Metals

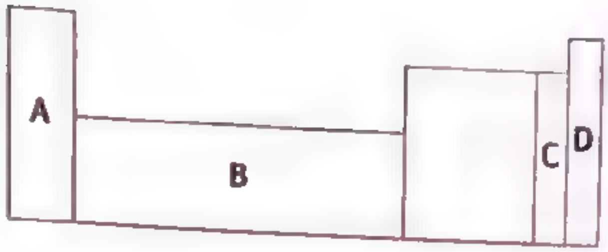
1. Their valence shell - generally - has less than half its capacity of electrons.
2. They have large atomic radius which leads to small values for ionization energy and electron affinity.
3. They are electropositive elements, due to their tendency to lose electrons of the valence shell and change into positive ions to reach the structure of the nearest noble gas.
4. They are good electric conductors, **due to the mobility** of their few valence electrons, which can transfer from one position to another in the metal structure.

B Nonmetals

1. Their valence shell - generally - has more than half its capacity of electrons.
2. They have small atomic radius which leads to high values for ionization energy and electron affinity.
3. They are electronegative eler... due to their tendency to ga... ...rons to form negative ions that ha... the same electron structure o... the nearest noble gas.
4. They don't conduct electricity (electric insulators), because th... valence electrons are strongly bound to the nucleus. Thus it is difficult for these valence electrons to be transferred.

Worked Example

The opposite figure represents a section in the periodic table.
In which of the illustrated zones can a diatomic molecule element which does not conduct electricity be found ?



ⓐ A ⓑ B
ⓒ C ⓓ D

Idea of answering :

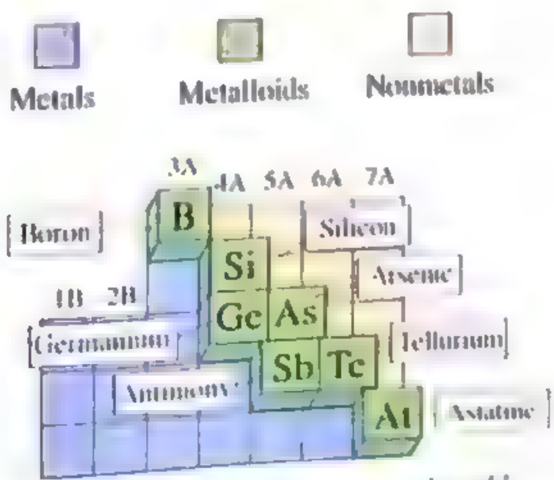
∵ Nonmetals and noble gases do not conduct electricity, and they lie on the right side of the periodic table.
∴ The choices ⓐ and ⓑ are excluded.

∵ Zone D in the periodic table contains the noble gases, and these are monatomic elements.
∴ The choice ⓓ is excluded.

Answer : The correct choice is ⓒ

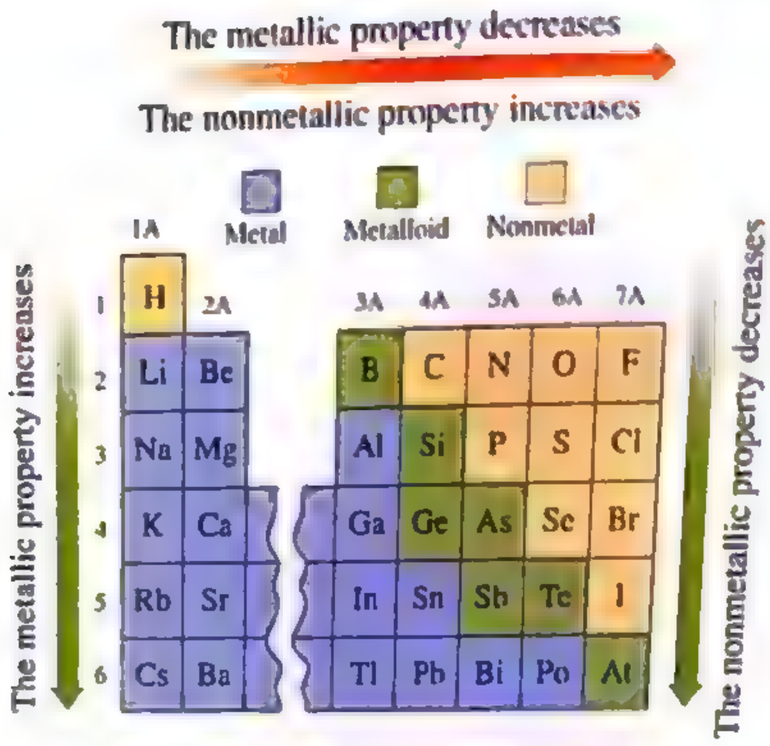
Metalloids

- **The metalloids are characterized by the following properties :**
  1. They have the metallic appearance and the most properties of nonmetals.
  2. Their electronegativity is intermediate between metals and nonmetals.
  3. Their electric conductivity is less than that of metals, but more than that of nonmetals.
  4. They are used in manufacturing some electronic instruments parts, such as transistors, as they are semiconductors.



The metalloids in the periodic table

The graduation of metallic and nonmetallic property in the periodic table



The graduation of the metallic and nonmetallic properties in the periodic table

In the same group

The metallic property increases (the nonmetallic property decreases) with the increase in the atomic number as we go down the group, **due to** their large atomic radius and the low ionization potential and electron affinity

In the same period

The period begins with the strongest metals in group 1A, then the metallic property decreases gradually by increasing the atomic number along the period till we reach the metalloids

To the right of the metalloids the nonmetallic property begins to appear

The period ends with the elements of the highest nonmetallic property in group 7A

Note

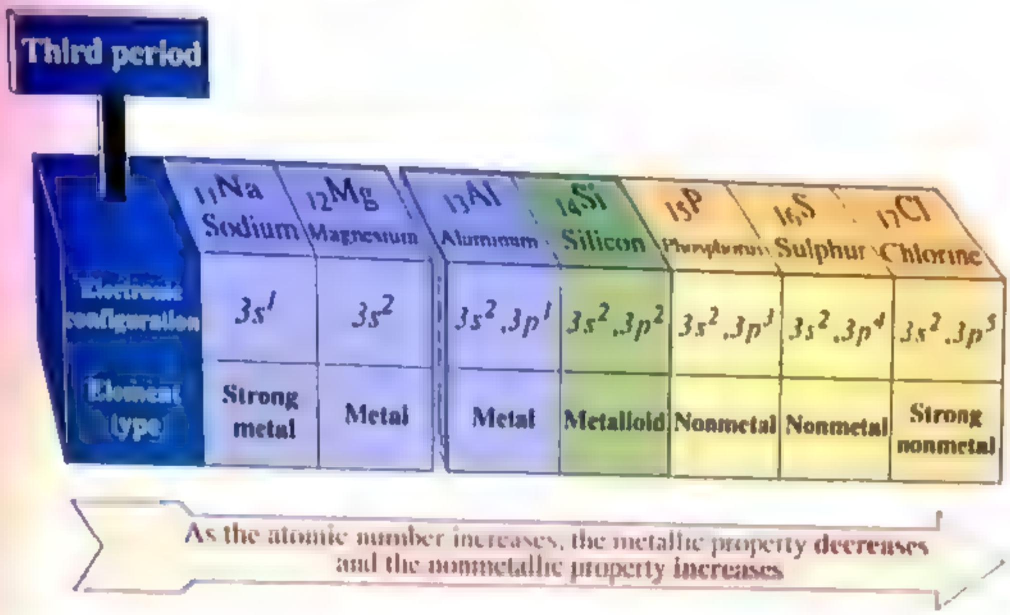
Cesium Cs is considered the most active metal
(loses its valence electron easily)
Because the metallic property increases in the same group by increasing the atomic number and it is located at the bottom of **the left hand side** of the table
(the metal with **the lowest ionization potential**)

While

Fluorine F is considered the most active nonmetal
(gains a new electron easily)
Because the nonmetallic property increases in the same period by increasing the atomic number and it is located at the top of **the right side** of the table
(the most electronegative nonmetal)

Application The graduation of metallic and nonmetallic property in the third period.

- **The following figure expresses** the graduation of metallic and nonmetallic property in the third period.
- **It is clear that** by increasing the atomic number, the metallic character **decreases** and the nonmetallic character **increases**.



Test Yourself

1. **Which of the following represents the electronic configuration of the most electropositive element ?**

   (a) $[He], 2s^1$ (b) $[Ne], 3s^2$
   (c) $[Xe], 6s^1$ (d) $[Xe], 6s^2$

Answer : The correct choice is ....

2. **The opposite table shows the ionization potentials of three metals A, B and C in the same period in the modern periodic table.**

Element	A	B	C
Ionization potential (kJ/mol)	2800	1500	700

What is the proper graduation of the metallic character of these elements ?

   (a) B < C < A (b) A < C < B
   (c) C < B < A (d) A < B < C

Answer : The correct choice is ....

6 Acidic and basic property

- When an element combines with oxygen, they form a compound known as ...
- There are three types of elements oxides, which are :

A Acidic oxides. **B** Basic oxides. **C** Amphoteric oxides.

A Acidic oxides

- The nonmetals oxides are usually known as acidic oxides.

because :

1. They dissolve in water forming oxygenated acids.

$$\underset{\text{Carbon dioxide}}{CO_{2(g)}} + \underset{\text{Water}}{H_2O_{(l)}} \longrightarrow \underset{\text{Carbonic acid}}{H_2CO_{3(aq)}}$$

$$\underset{\text{Sulphur trioxide}}{SO_{3(g)}} + \underset{\text{Water}}{H_2O_{(l)}} \longrightarrow \underset{\text{Sulphuric acid}}{H_2SO_{4(aq)}}$$

2. They react with alkalis forming salt and water.

$$\underset{\text{Carbon dioxide}}{CO_{2(g)}} + \underset{\text{Sodium hydroxide}}{2NaOH_{(aq)}} \longrightarrow \underset{\text{Sodium carbonate}}{Na_2CO_{3(aq)}} + \underset{\text{Water}}{H_2O_{(l)}}$$

> **Among the acidic ...**
> - Carbon dioxide ...
> - Sulphur trioxide ...
> - Nitrogen dioxide ...

Test Yourself

Write the balanced symbolic equation which represents the reaction of sulphur trioxide with sodium hydroxide.

....

B Basic oxides

- The metals oxides are usually known as basic oxides.
- Some basic oxides are not soluble in water and others are soluble in water forming alk... the water soluble basic oxides are also known as alkali oxides.

$$\underset{\text{Sodium oxide}}{Na_2O_{(s)}} + \underset{\text{Water}}{H_2O_{(l)}} \longrightarrow \underset{\text{Sodium hydroxide}}{2NaOH_{(aq)}}$$

$$\underset{\text{Potassium oxide}}{K_2O_{(s)}} + \underset{\text{Water}}{H_2O_{(l)}} \longrightarrow \underset{\text{Potassium hydroxide}}{2KOH_{(aq)}}$$

> **Among the basic oxides**
> - Sodium oxide Na_2O
> - Potassium oxide K_2O
> - Magnesium oxide MgO

- They react with acids forming salt and water :

$$\underset{\text{Sodium oxide}}{Na_2O_{(s)}} + \underset{\text{Hydrochloric acid}}{2HCl_{(aq)}} \longrightarrow \underset{\text{Sodium chloride}}{2NaCl_{(aq)}} + \underset{\text{Water}}{H_2O_{(l)}}$$

$$\underset{\text{Magnesium oxide}}{MgO_{(s)}} + \underset{\text{Sulphuric acid}}{H_2SO_{4(aq)}} \longrightarrow \underset{\text{Magnesium sulphate}}{MgSO_{4(aq)}} + \underset{\text{Water}}{H_2O_{(l)}}$$

Test Yourself

Write the balanced symbolic equation which indicates :

(1) The dissolution of calcium oxide in water.

(2) The reaction of calcium oxide with phosphoric acid.

C Amphoteric oxides

Amphoteric oxides are elements oxides that react with acids as basic oxides and react with alkalis as acidic oxides forming in both cases salt and water.

Among the amphoteric oxides

- Aluminum oxide Al_2O_3
- Zinc oxide ZnO
- Antimony oxide Sb_2O_3
- Tin (II) oxide SnO

$$\underset{\text{Zinc oxide}}{ZnO_{(s)}} + \underset{\text{Sulphuric acid}}{H_2SO_{4(aq)}} \longrightarrow \underset{\text{Zinc sulphate}}{ZnSO_{4(aq)}} + \underset{\text{Water}}{H_2O_{(l)}}$$

$$\underset{\text{Zinc oxide}}{ZnO_{(s)}} + \underset{\text{Sodium hydroxide}}{2NaOH_{(aq)}} \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_{2(aq)}} + \underset{\text{Water}}{H_2O_{(l)}}$$

Test Yourself

Write the balanced symbolic equation which indicates :

(1) The reaction of tin (II) oxide with nitric acid.

(2) The reaction of tin (II) oxide with sodium hydroxide.

Worked Example

Neutral oxides react neither with acids nor with bases.
Which of the following substances are neutral oxides ?

ⓐ NO_2 , Na_2O ⓑ CO , NO
ⓒ SnO , K_2O ⓓ CO_2 , NO_2

Idea of answering :

∵ The oxides Na_2O and K_2O are basic oxides which react with acids.
∴ The choices ⓐ and ⓒ are excluded.

∵ The oxides CO_2 and NO_2 are acidic oxides which react with bases.
∴ The choice ⓓ is excluded.

Answer : The correct choice is ⓑ

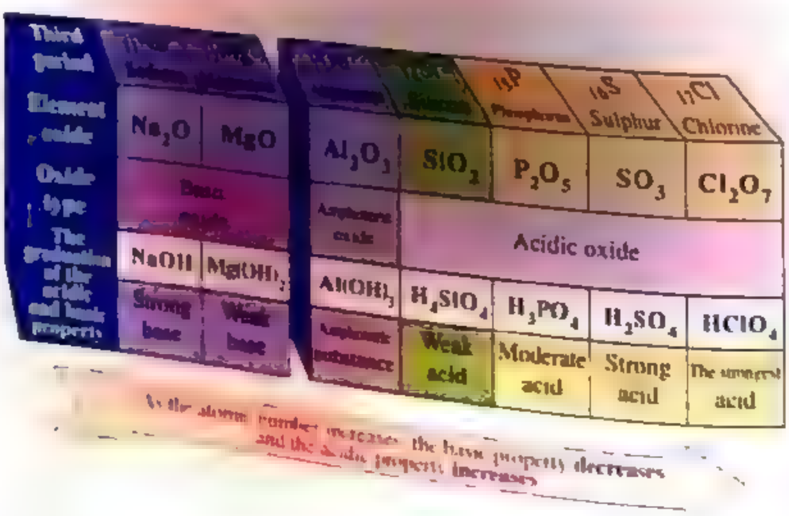
The graduation of acidic and basic property in the periodic table

In the period	In the group	
	In the group which starts with a metal	In the group whi[...] starts with a nonn[...]
The basic property of the oxide decreases as the atomic number of the element increases, while the acidic property increases	The basic property of the oxide increases as the atomic number of the element increases, as in group 1A	The acidic pro[...] of the hydrogen co[...] increases as the at[...] of the element i[...] as in grou[...]

Application

The graduation of acidic and basic property in the third period.

- The following figure expresses the graduation of acidic and basic property in th[...] period. It is shown that, as the atomic number increases the basic property dec[...] the acidic property increases.



Note

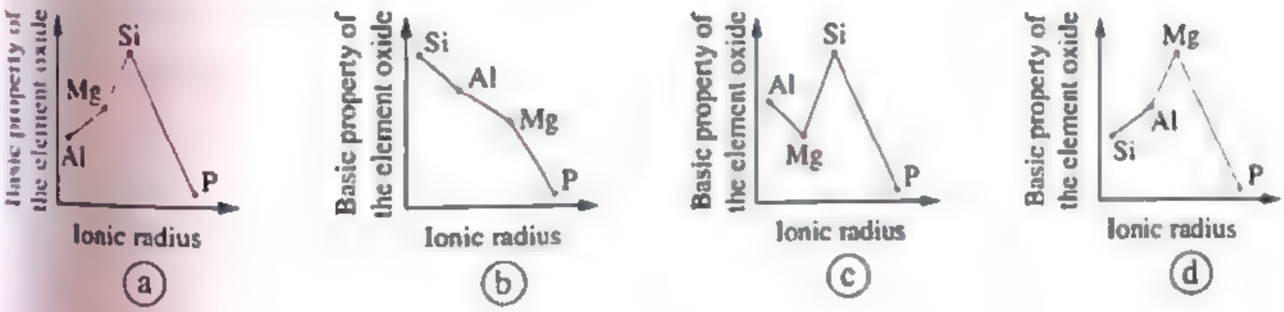
- The acidic property of hydrogen compounds of group 17 (halogens) increases as the atomic number increases.

because the increase in the atomic number in the group elements leads to the increase in the atomic radius of the halogen, therefore its attraction force to hydrogen atom decreases, making it easier to be ionized.

The graduation of acidic property of halogens

Worked Example

Which of the following graphs represents the relation between the basic property of the element oxide and its ionic radius ?



Idea of answering :

∵ The basic property of the elements oxides decreases by increasing their atomic numbers in the same period.

∴ The basic property of aluminum oxide is less than that of magnesium oxide.

∴ The choices (b) and (c) are excluded.

∵ The basic property of silicon oxide is less than that of aluminum oxide.

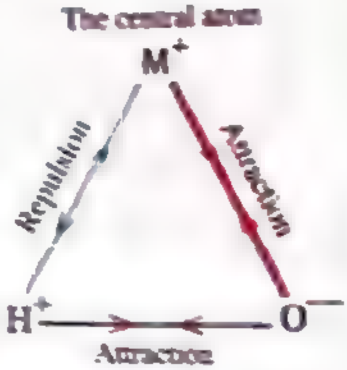
∴ The choice (a) is excluded.

Answer : The correct choice is (d).

The acidic and basic property of the hydroxy compounds

- The oxygenated acids (acids contain oxygen) and bases are considered as hydroxy compounds, they can be represented by the general formula (MOH), where M represents the element atom.
- The hydroxy compounds can be ionized by either ways :

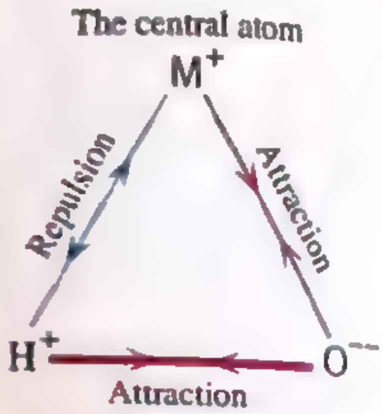
As an acid



- The compound will be ionized as an acid if : The (M – O) bond is stronger than the (O – H) bond.
(i.e. The attraction between M^+ and O^{--} is stronger than that between H^+ and O^{--}).

$$\underset{\text{Oxygenated acid}}{MOH} \rightleftharpoons MO^- + \underset{\text{Positive hydrogen ion}}{H^+}$$

As a base

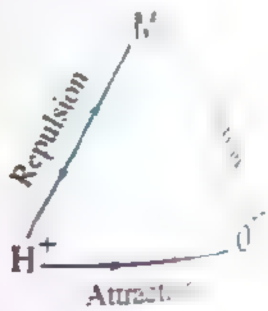


- The compound will be ionized as a base if : The (O – H) bond is stronger than the (M – O) bond.
(i.e. The attraction between H^+ and O^{--} is stronger than that between M^+ and O^{--}).

$$\underset{\text{Base}}{MOH} \rightleftharpoons M^+ + \underset{\text{Negative hydroxide ion}}{OH^-}$$

Note

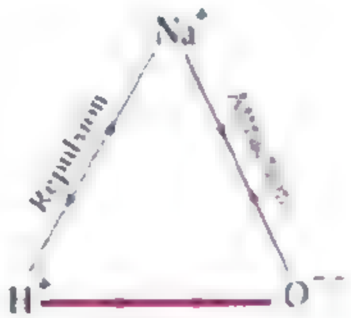
If the strength of (M – O) bond and the strength of (O – H) bond are equal, the substance will be ionized as an acid or a base depending on the reaction medium, this means that it reacts as a base in the acidic medium and as an acid in the basic medium.



- In general, the attraction between each of (O^{--}, M^+) and (O^{--}, H^+) depends on :
- The volume of M atom.
- The charge of M in the compound.

Application The basic property of sodium hydroxide compound.

- Sodium hydroxide is ionized as a base.
- Where sodium atom has a large volume
- and its ion has only one positive charge.
- Accordingly, the attraction between Na^+
- and O^{--} decreases
- i.e. The (O – H) bond is stronger than
- that of the (Na – O) bond.
- So OH^- ion is produced.



Attraction forces in NaOH compound

$$\underset{\text{Sodium hydroxide}}{NaOH} \rightleftharpoons \underset{\text{Sodium ion}}{Na^+} + \underset{\text{Hydroxide ion}}{OH^-}$$

Worked Example

Assisted by the electronegativities of the elements shown in the opposite table. What is the correct order which indicates the strength of the acids in the following choices ?

Element	Electronegativity
Cl	3
Br	2.8
I	2.5

ⓐ HIO > HBrO > HClO
ⓑ HClO > HBrO > HIO
ⓒ HIO > HClO > HBrO
ⓓ HBrO > HClO > HIO

Idea of answering :

- The strength of the oxygenated acid increases when the electronegativity of its central atom increases.

Answer : The correct choice is ⓑ

Test Yourself

Four elements P , Q , R and S are located in p-block in the third period in the periodic table, they are ordered according to electronegativity as follows : S > R > Q > P
Which of the following bonds liberates H^+ ion easier ?

ⓐ P – O – H
ⓑ S – O – H
ⓒ Q – O – H
ⓓ R – O – H

Answer : The correct choice is ....

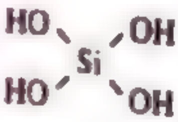
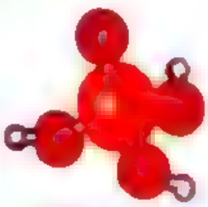
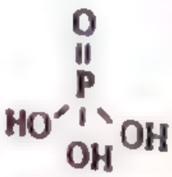
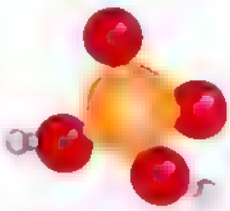
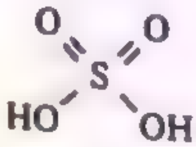
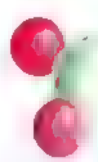
The strength of the oxygenated acids (oxyacids)

- The oxygenated acids are represented by the following general formula :

The central element atom — The number of oxygen atoms nonbinded with hydrogen — The number of oxygen atoms binded with hydrogen

$$MO_n(OH)_m$$

- The strength of the oxygenated acid (oxyacid) increases as the number of nonbinded oxygen atoms (O_n) with hydrogen increases as shown in the following table :

Acid anion	Silicate group SiO_4^{4-}	Phosphate group PO_4^{3-}	Sulphate group SO_4^{2-}	Perchlorate g... ClO_4^-
Oxygenated acid (oxyacid)	Orthosilicic acid H_4SiO_4	Orthophosphoric acid H_3PO_4	Sulphuric acid H_2SO_4	Perchlor... acid $HClO_4$
Hydroxy formula $MO_n(OH)_m$	 $Si(OH)_4$ 	 $PO(OH)_3$ 	 $SO_2(OH)_2$ 	 ClO... 
Ratio n : m	0 : 4	1 : 3	2 : 2	3
No. of nonbinded oxygen atoms with hydrogen	zero	1	2	[illegible]
Strength of the acid	Weak	Moderate	Strong	The strong...

Worked Example

Among the oxygenated acids are :

$\boxed{HBrO_3}$, $\boxed{HBrO_2}$, $\boxed{HBrO}$

Which of the following is correct for these acids ?

a) HBrO is the weakest acid among these three acids.

b) Oxidation number of bromine in $HBrO_3$ equals (–1).

c) $HBrO_2$ is the strongest acid among these three acids.

d) The ratio (n : m) in HBrO equals (1 : 1).

Idea of answering :

The following table exhibits the hydroxy formulas of these oxygenated acids, and (n : m) ratio in each of them :

Oxygenated acid	HBrO	$HBrO_2$	$HBrO_3$
Hydroxy formula	Br(OH)	BrO(OH)	$BrO_2(OH)$
n : m	0 : 1	1 : 1	2 : 1

∵ The strength of the oxygenated acid increases by increasing the number of nonbinded oxygen atoms with hydrogen.

∴ These acids are ordered ascendingly according to the strength as follows :

$$HBrO < HBrO_2 < HBrO_3$$

Answer : The correct choice is a

Summary of the graduation of the properties of the elements in the periodic table

- **Trends and periodicity of properties in the periodic table :**

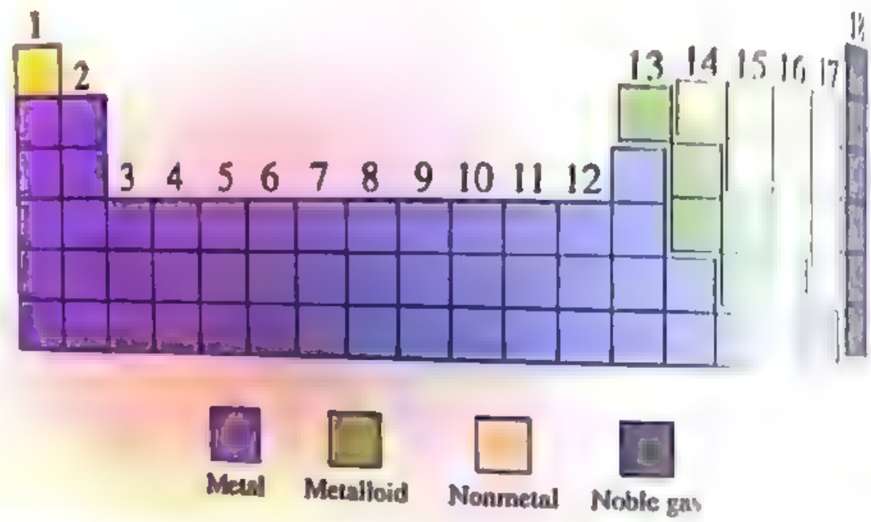
By increasing the atomic number

The following increases :
- The atomic radius.
- The metallic property.
- The acidic property of the nonmetals of group 7A.
- The basic property of metals.

The following decreases :
- The ionization potential.
- The electron affinity.
- The electronegativity.
- The nonmetallic property.

The following increases :
- The ionization potential.
- The electron affinity.
- The electronegativity.
- The nonmetallic property.
- The acidic property.

The following decreases :
- The atomic radius.
- The metallic property.
- The basic property.



Graduation of properties of the elements in the periodic table

Ready

Preliminary questions to remember the principal concepts in the lesson

Answer them yourself

1 Choose the correct answer for each of the following sentences :

(1) The nonmetals are characterized by ....

a. high ionization energy.

b. being electropositive elements.

c. small electron affinity.

d. large atomic radius.

(2) Arsenic $_{33}As$ and antimony $_{51}Sb$ are similar in ....

a. being both from the fourth period elements.

b. being both from group (5A).

c. being better electrical conductors than the other metals.

d. the four quantum numbers of the last electron in the atom of each of them.

(3) Sulphuric acid does not react with ....

a. MgO

b. CO_2

c. Al_2O_3

d. Na_2O

(4) What is the substance which dissolves in water forming an alkaline solution ?

a. MgO

b. Al_2O_3

c. SiO_2

d. SO_2

(5) Zinc oxide reacts with caustic soda as a (an) ......

a. amphoteric oxide.

b. acidic oxide

c. basic oxide.

d. neutral oxide.

(6) In the opposite figure, ...

a. the attraction of O^{2-} to H^+ ion increases.

b. the attraction of O^{2-} to Na^+ ion increases.

c. the strength of the bond between O^{2-} and Na^+ increases.

d. an ionization occurs, and an acid is produced.

(7) The strength of the oxygenated acids depends on the number of the ......

a. hydrogen atoms.

b. oxygen atoms linked to hydrogen atoms.

c. oxygen atoms unlinked to hydrogen atoms.

d. hydrogen atoms unlinked to the nonmetal atoms.

(8) What is the acid which the ratio (n : m) in its hydroxy formula is (3 : 1) ?

a. H_4SiO_4

b. H_3PO_4

c. H_2SO_4

d. $HClO_4$

2 Illustrate with the balanced symbolic equations :

(1) The dissolution of sulphur trioxide gas in water.

(2) The reaction of carbon dioxide gas with sodium hydroxide.

(3) The dissolution of potassium oxide in water.

(4) The reaction of sodium oxide with hydrochloric acid.

(5) Zinc oxide is an amphoteric oxide.

Answered

Multiple choice questions

Metallic and nonmetallic property

1 **Upon the classification of the elements, Berzelius might have relied on ....**

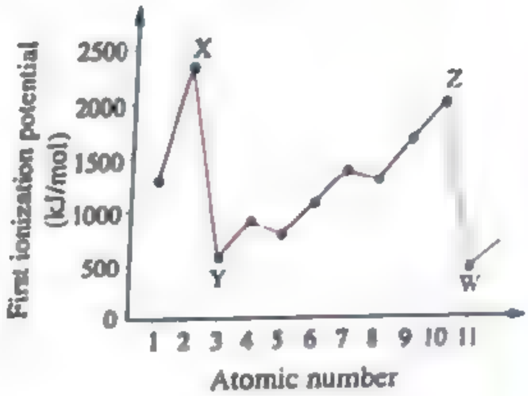
(a) their atomic numbers.

(b) their electron configurations.

(c) their degree of electrical and heat conductivity.

(d) the quantum numbers of the last electron in the atom of each of them.

2 **Which of the illustrated elements in the opposite figure loses its valence electrons more easily ?**



(a) X

(b) Y

(c) Z

(d) W

3 **What is the element which can form an ion with charge –2 ?**

(a) Selenium $_{34}Se$

(b) Silicon $_{14}Si$

(c) Strontium $_{38}Sr$

(d) Iodine $_{53}I$

4 **Which of the following sets of elements includes a nonmetal, a metal and a metalloid respectively ?**

(a) H , Zn , I

(b) Zn , I , Br

(c) Zn , Cu , Si

(d) I , Zn , Si

5 **Which of the following choices represents the electron configuration of the most active metal and the most active nonmetal ?**

Choices	The most active metal	The most active nonmetal
(a)	$[Ar], 4s^2, 3d^1$	$[Ar], 4s^2, 3d^{10}, 4p^6$
(b)	$[Xe], 6s^1$	$1s^2, 2s^2, 2p^5$
(c)	$1s^1$	$1s^2, 2s^2, 2p^3$
(d)	$[Kr], 5s^1$	$[Ne], 3s^2, 3p^5$

6 **Nitrogen gas is less active than fluorine gas, because ....**

(a) the boiling point of nitrogen is less than that of fluorine.
(b) the molar mass of nitrogen is less than that of fluorine.
(c) the atomic radius of nitrogen is larger than that of fluorine.
(d) the electronegativity of nitrogen is higher than that of fluorine.

7 **The opposite figure represents a section in the periodic table : What is the letter which refers to the element that is characterized by having a small atomic radius and not conducting electricity ?**

(a) A (b) B
(c) C (d) D

Acidic and basic property

8 **Element (X) reacts with oxygen forming a gas whose aqueous solution turns blue litmus paper into red. What is the location of (X) in the periodic table ?**

Choices	Period	Group
(a)	2	1
(b)	2	2
(c)	3	16
(d)	3	2

Among the properties of some nonmetallic elements are :

Property (1) : One of its oxides dissolves in water forming a strong acid.

Property (2) : Its last $3p$ sublevel does not contain any paired electrons.

Which of the following is (are) applicable for each of phosphorus $_{15}P$ and sulphur $_{16}S$ elements ?

Choices	Phosphorus	Sulphur
(a)	(1) and (2)	(1) only
(b)	(1) only	(1) and (2)
(c)	(1) and (2)	(1) and (2)
(d)	(2) only	(1) only

The opposite table shows some elements of the third and fourth periods in the periodic table.

3rd period	Al	Si	P	S
4th period	Ga	Ge	As	Se

What is (are) the element(s) of the fourth period whose oxide(s) dissolve(s) in water forming acidic solution ?

(a) As and Ga
(b) Ga and Ge
(c) Ga and Se
(d) Se only.

A mixture is composed of the oxides of two elements located in the third period in the periodic table, and after their reaction together, the product dissolves in water forming an almost neutral solution.

What are the two oxides composing this mixture ?

(a) Al_2O_3 and N_2O
(b) Na_2O and MgO
(c) Na_2O and P_4O_{10}
(d) SO_3 and P_4O_{10}

12 Here are six different compounds, which are :

Na_2O , Al_2O_3 , H_2O , ZnO , CO , SO_2

What are the correct numbers of the types of these compounds ?

Choices	Acidic compounds	Basic compounds	Amphoteric compounds	Neutral compounds
(a)	1	2	2	1
(b)	1	1	3	1
(c)	2	2	0	2
(d)	1	1	2	2

13 What is the formula of the oxide of the element (M) which is located in group (3A) in the periodic table ?

(a) M_2O_3
(b) M_3O_2
(c) MO
(d) M_3O_4

14 Why does aluminum oxide disappear on adding a little amount of it to sodium hydroxide solution with stirring ?

(a) Because aluminum $_{13}Al$ is located in the same period of sodium $_{11}Na$
(b) Because aluminum oxide reacts as a base with sodium hydroxide.
(c) Because the basic property decreases in the same period by increasing the atomic number.
(d) Because aluminum oxide reacts as an acid with sodium hydroxide.

15 The four quantum numbers of the last electron in the atom of the element (X) are : ($n = 3$, $\ell = 0$, $m_\ell = 0$, $m_s = +\frac{1}{2}$).

Which of the following choices represents correctly the element (X) ?

Choices	Its oxide is basic	Its ionization potential is small	Its oxide is amphoteric	Its electronegativity is high
(a)	✗	✓	✓	✗
(b)	✓	✓	✗	✗
(c)	✓	✗	✗	✓
(d)	✗	✗	✓	✓

16 The weakest oxygenated acid in the fourth period in the periodic table is ....

ⓐ $Ge(OH)_4$
ⓑ $BrO_3(OH)$
ⓒ $AsO(OH)_3$
ⓓ $SeO_2(OH)_2$

17 Among the strong acidic solutions is ....

ⓐ $SO_2(OH)_2$
ⓑ $PO(OH)_3$
ⓒ $Ca(OH)_2$
ⓓ $Al(OH)_3$

18 Which of the following oxygenated acids is the strongest ?

ⓐ $HOCl$
ⓑ HNO_2
ⓒ H_2SO_3
ⓓ HNO_3

19 Perchloric acid is a ....

ⓐ monohydric acid.
ⓑ dihydric acid.
ⓒ trihydric acid.
ⓓ tetrahydric acid.

20 Element (M) is located in group (5A).
What is the probable hydroxy formula of its oxygenated acid ?

ⓐ $M(OH)_4$
ⓑ $MO(OH)_3$
ⓒ $MO_2(OH)_2$
ⓓ $MO_3(OH)$

21 What is the probable electronic configuration of the last sublevel in the atom of the element (M) whose oxygenated acid has the formula $MO_2(OH)_2$?

ⓐ $3p^2$
ⓑ $3p^3$
ⓒ $3p^4$
ⓓ $3p^5$

22 What is the anion which forms the strongest oxygenated acid ?

ⓐ SO_4^{2-} ⓑ ClO_2^- ⓒ ClO_3^- ⓓ ClO_4^-

23 From these equations :

- $Pb(OH)_{2(s)} + 2HNO_{3(aq)} \longrightarrow Pb(NO_3)_{2(aq)} + 2H_2O_{(l)}$
- $Pb(OH)_{2(s)} + 2NaOH_{(aq)} \longrightarrow Na_2PbO_{2(aq)} + 2H_2O_{(l)}$

It is concluded that ....

ⓐ the basic property of $Pb(OH)_2$ is stronger than its acidic property.
ⓑ the aqueous solution of $Pb(OH)_2$ is amphoteric.
ⓒ $Pb(OH)_2$ as an acid is stronger than its strength as a base.
ⓓ (Pb – O) bond strength is equal that of (O – H) bond.

24 In the opposite figure, if the bond (O – H) is stronger than the bond (M – O), then the electron configuration of the element (M) may end with the sublevel ....

(a) $2s^1$
(b) $1s^2$
(c) $2p^2$
(d) $2p^1$

Essay questions

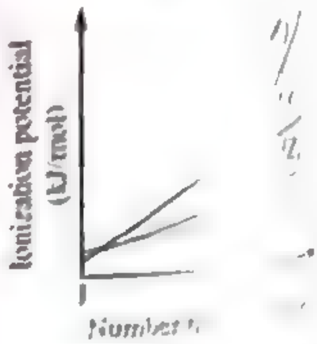
25 The opposite table represents the quantum numbers of the last electron in the atom of each of (X) and (Y) elements :

(1) Write the electronic configurations of the two elements.

(2) Which of them is electropositive ? Explain.

Element	Quantum numbers			
	(n)	(l)	(m_l)	(m_s)
(X)	3	1	0	$-\frac{1}{2}$
(Y)	3	0	0	$+\frac{1}{2}$

26 In the opposite figure, replace the letters (X), (Y) and (Z) with what is suitable from the elements $_{12}Mg$, $_{13}Al$ and $_{19}K$ and arrange them according to the metallic property.



27 Aluminum oxide reacts with sodium hydroxide forming sodium aluminate whose molecule contains a sodium atom, an aluminum atom and two oxygen atoms. Write the balanced symbolic equation which represents the reaction of aluminum oxide with .

(1) Sodium hydroxide.

(2) Sulphuric acid.

28 Why does cesium hydroxide ionize as a base, while $ClO_3(OH)$ ionizes as an acid ?

29 The following table represents the third period in the modern periodic table :

IA	IIA	IIIA	IVA	VA	VIA	VIIA	0
A	B	C	D	E	X	Y	Z

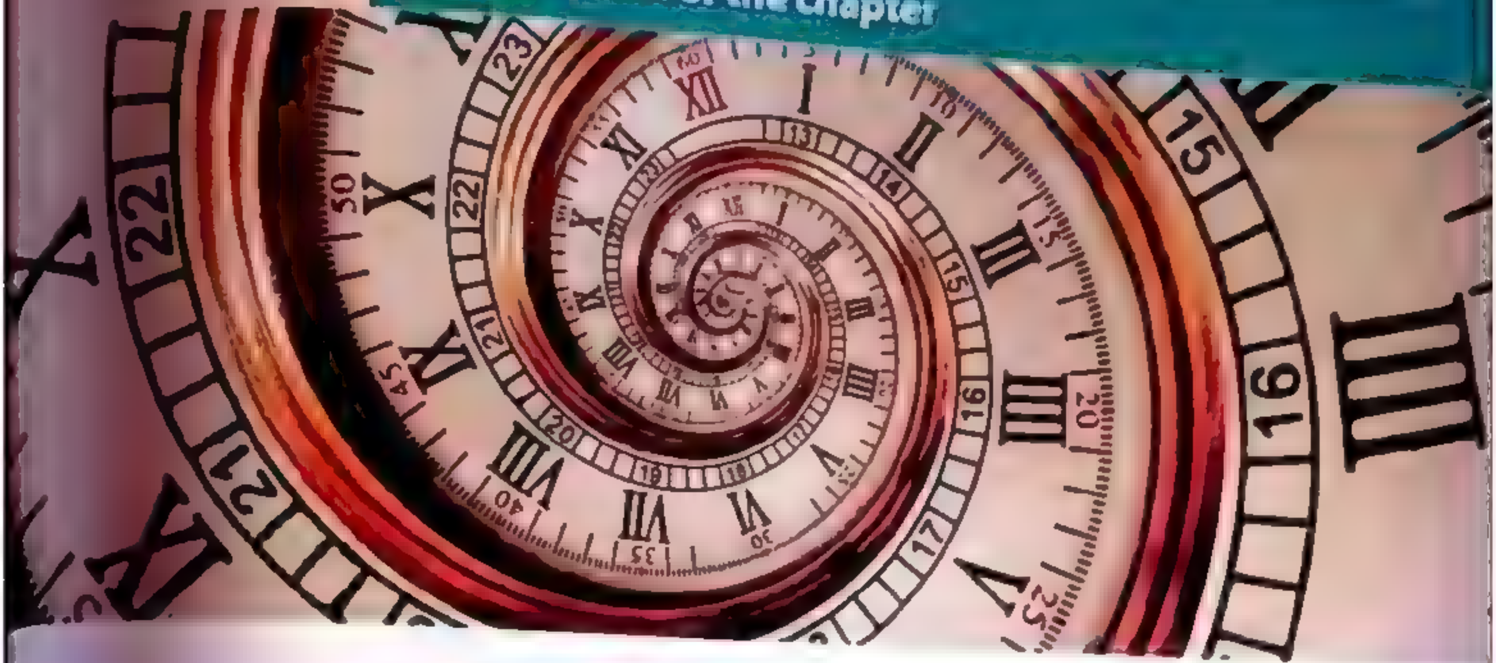
(1) What is the number of oxygen atoms nonbonded to hydrogen in the oxygenated acid of the element (Y) ?

(2) Why is the oxide of the element (A) basic oxide ?

Lesson Four

From The oxidation numbers

Until The end of the chapter



Oxidation numbers (states)

Oxidation number is a number that refers to the electric charge (positive or negative) that the atom or ion would carry in the compound, whether it is an ionic or a covalent compound.

The significance of oxidation numbers :

The significance of positive and negative oxidation numbers in the ionic compounds differs from that of the oxidation numbers in the covalent compounds.

	In ionic compounds	In covalent compounds
Positive oxidation number indicates	The number of electrons that the atom has lost to give a positive ion (cation)	The shift of the electrons away from the less electronegative atom
Negative oxidation number indicates	The number of electrons that the atom has gained to give a negative ion (anion)	The shift of the electrons towards the more electronegative atom

Rules for calculating the oxidation numbers

Rule	Application
1 The oxidation number of the element atom in the molecule of similar atoms equals zero, whatever the number of the molecule atoms, because the sharing of electrons between the atoms is equal.	see table 1
2 The oxidation number of the element ion equals the charge (valence) of the ion.	see table 2
3 The oxidation number of the atomic group equals the charge of the group.	see table 3
4 The oxidation number of any metal in : • Group 1A elements equals +1 • Group 2A elements equals +2 • Group 3A elements equals +3	see table 4
5 The oxidation number of fluorine in all its compounds equals –1, because its electronegativity is greater than that of all other elements.	see table 5
6 The oxidation numbers of chlorine, bromine and iodine **(halogens)** in most of their compounds equal (–1), however their other oxidation numbers can be calculated mathematically (as will be discussed later).	see table 6

Table 1

Molecule	Na	Cl_2	P_4	S_8
Oxidation number of element atom	zero			

Table 2

Ion	Ag^{+}	Cu^{2+}	Fe^{3+}	Cl^{-}	O^{2-}	[illegible]
Oxidation no.	+1	+2	+3	–1	–2	[illegible]

Table 3

Atomic group	$(NH_4)^{+}$ Ammonium gp.	$(OH)^{-}$ Hydroxide gp.	$(NO_3)^{-}$ Nitrate gp.	$(CO_3)^{2-}$ Carbonate gp.	$(SO_4)^{2-}$ Sulphate gp.	[illegible]
Oxidation no.	+1	–1	–1	–2	–2	[illegible]

Table 4

Compound molecule	KNO_3	$MgSO_4$	[illegible]
Oxidation no. of the metal	+1	+2	[illegible]

Table 5

Compound molecule	HF	KF
Oxidation no. of fluorine	–1	

Table 6

Compound molecule	$LiCl$	$NaBr$
Oxidation no. of the halogen	–1	

1 The oxidation number of oxygen in most of its compounds is –2 , while its oxidation number in : • Peroxides equals –1 • Superoxides equals $-\frac{1}{2}$ • Its compound with fluorine equals +2	

Oxide	Normal oxide	Peroxide		Super oxide	With fluorine
Formula	Na_2O	H_2O_2	Na_2O_2	KO_2	OF_2
Oxidation no. of oxygen	–2	–1		$-\frac{1}{2}$	+2

2 The oxidation number of hydrogen in most of its compounds is +1, except in its compounds with active metals which are known as active metal hydrides, its oxidation number is –1

Compound molecule	HCl	NaH	CaH_2	AlH_3
Oxidation no. of hydrogen	+1	–1	–1	–1

Active metal hydrides are ionic compounds formed from the combination of an active metal with hydrogen in which hydrogen has an oxidation number –1 (negative ion).

3 The algebraic summation of the oxidation numbers of the different atoms in the molecule equals zero.

In sodium chloride molecule NaCl :

The oxidation no. of Na (+1) + The oxidation no. of Cl (–1) = zero

4 The algebraic summation of the oxidation numbers of the atomic groups forming the molecule equals zero.

In the molecule $[NH_4]^+[NO_2]^-$:

The oxidation no. of ammonium group (+1) + The oxidation no. of nitrite group (–1) = zero

5 The algebraic summation of the oxidation numbers of the different atoms in an atomic group equals the charge of the group.

In hydroxide group OH^- :

The oxidation no. of oxygen (–2) + The oxidation no. of hydrogen (+1) = –1

6 Some elements, especially the transition elements have several oxidation numbers which can be calculated by knowing the oxidation numbers of the other elements.

Note

Hydrogen gas evolves

At the anode (the positive electrode) during the electrolysis of sodium hydride melt	At the cathode (the negative electrode) during the electrolysis of the acidified ...

Because

The oxidation number of hydrogen in sodium hydride NaH melt is (−1) (i.e. a negative hydrogen ion)	The oxidation number of hydrogen in acidified water H_2O is (+1) (i.e. a positive hydrogen ion)

How to assign the oxidation number of an unknown element in a given compound or atomic group

Steps	Application (1)	Application (2)
❶ Write the oxidation number of each known element above its atom symbol in the compound molecule or atomic group formula.	$\overset{+1}{K_2}\ \overset{?}{Cr_2}\ \overset{-2}{O_7}$	? ... (C(
❷ Multiply the oxidation number of each element by the number of its atoms in the molecule.	$K_2\ Cr_2\ O_7$ (1 × 2) (−2 × 7)	(C((−
❸ Assign the oxidation number of unknown element knowing that : • The algebraic summation of the atoms of the different elements in the molecule equals zero. • The algebraic summation of the atoms of the different elements in the atomic group equals the charge of the group.	$2 + 2Cr - 14 = 0$ $2Cr = +12$ $Cr = +6$	C + (− C = C =

Worked Examples

❶ **Calculate the oxidation number of :**

(1) Chlorine in : (a) Cl_2 (b) $KClO_4$

(2) Sulphur in : (a) $(SO_4)^{2-}$ (b) $Na_2S_2O_3$

(3) Chromium in : $Cr_2(SO_4)_3$

(4) Nitrogen in : $(NH_4)^+(NO_2)^-$

Answer :

$2Cl = 0$ $\quad\therefore Cl =$

$\overset{+1\ ?\ -2}{KClO_4}$ $\quad , 1 + Cl + (-2 \times 4) = 0$ $\quad , Cl - 7 = 0 \quad \therefore Cl = +7$

(2) $\overset{?\ -2}{(SO_4)^{2-}}$ $\quad , S + (-2 \times 4) = -2$ $\quad , S = -2 + 8 \quad \therefore S = +6$

(b) $\overset{+1\ ?\ -2}{Na_2S_2O_3}$ $\quad , (+1 \times 2) + 2S + (-2 \times 3) = 0$ $\quad , 2S = +4 \quad \therefore S = +2$

(3) $\overset{?}{Cr_2}(SO_4)_3^{2-}$ $\quad , 2Cr + (-2 \times 3) = 0$ $\quad , 2Cr = +6 \quad \therefore Cr = +3$

(4) $(NH_4)^+(NO_2)^-$ is an ionic compound which consists of two atomic groups, the oxidation number of nitrogen in each of them is different.

$\overset{?\ +1}{(NH_4)^+}$ $\quad , N + (+1 \times 4) = +1$ $\quad , N = 1 - 4 \quad \therefore N = -3$

$\overset{?\ -2}{(NO_2)^-}$ $\quad , N + (-2 \times 2) = -1$ $\quad , N = -1 + 4 \quad \therefore N = -3$

---

8 The nucleus of manganese atom Mn contains 25 protons.

What is the electron configuration of manganese in $Mn_3(PO_4)_2$?

(a) [Ar] , $3d^6$

(b) [Ar] , $3d^5$

(c) [Ar] , $3d^3$, $4s^2$

(d) [Ar] , $3d^5$, $4s^2$

Idea of answering : -

The oxidation number of manganese in $Mn_3(PO_4)_2$:

$3Mn + (2 \times -3) = 0$

$\therefore Mn = +2$

$\because$ The electron configuration of manganese atom is :

${}_{25}Mn$: [Ar] , $4s^2$, $3d^5$

$\therefore$ The electron configuration of Mn^{2+} ion is :

${}_{25}Mn^{2+}$: [Ar] , $3d^5$

Answer : The correct choice is (b)

Test Yourself

What are the two ions which form the compound K_3P ?

ⓐ K^+ , P^{3-}

ⓑ K^{3+} , P^-

ⓒ K^+ , P^-

ⓓ K^{3+} , P^{3-}

Idea of answering :

∵ The oxidation number of potassium in any of its compounds is ....

∴ The choices .... and .... are excluded.

∵ The oxidation number of phosphorus in K_3P is :

$(3 \times ....) + P = 0$

∴ P = ...

∴ The choice .... is excluded.

Answer : The correct choice is ....

Worked Example

The opposite table shows the oxidation numbers of three elements A , B and C in a compound.

What is the probable molecular formula of this compound ?

Element	Oxidation number
A	+2
B	+5
C	−2

ⓐ $A_3(B_4C)_2$

ⓑ $A_3(BC_4)_2$

ⓒ $A_2(BC_3)_2$

ⓓ ABC_2

Idea of answering :

∵ The algebraic summation of the oxidation numbers of the atoms composing the compound must equal zero.

∴ The probable molecular formula is the one in which the algebraic summation of the oxidation numbers of the atoms equals zero.

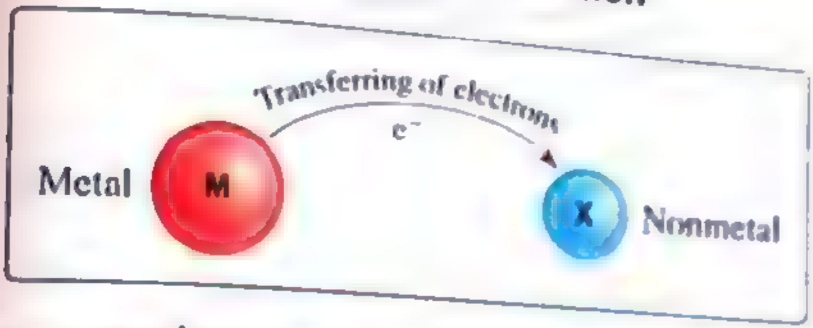
ⓐ	$A_3(B_4C)_2$	$(+2 \times 3) + (+5 \times 4 \times 2) + (-2 \times 2) = 6 + 40 - 4 = +42$	✗
ⓑ	$A_3(BC_4)_2$	$(+2 \times 3) + (+5 \times 2) + (-2 \times 4 \times 2) = 6 + 10 - 16 = 0$	✓

Answer : The correct choice is ⓑ

Calculating the change of the oxidation number in an oxidation-reduction reaction (redox reaction)

- The advantage of using oxidation numbers is that they can help us in determining the type of chemical change occurring to an element during the chemical reaction.

In the chemical reaction

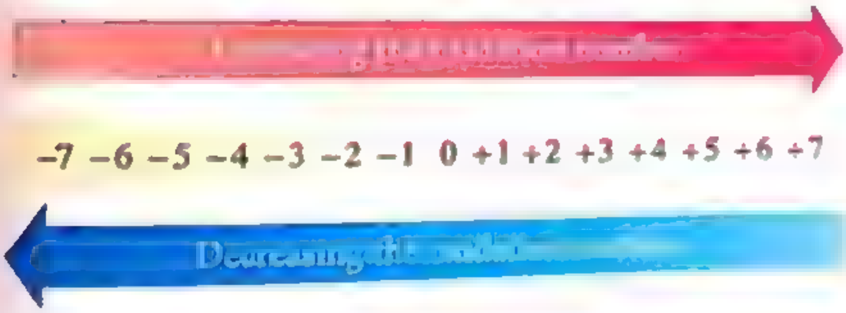


The metal loses one or more electrons (undergoes oxidation).
, so its oxidation number increases.
The metal in this case is the reducing agent.

The nonmetal gains one or more electrons (undergoes reduction).
, so its oxidation number decreases
The nonmetal in this case is the oxidizing agent.

Oxidation

It is the process of losing electrons resulting in increasing the positive charge



Reduction

It is the process of gaining electrons resulting in decreasing the positive charge

Oxidation-reduction process involves changing in the oxidation numbers

Note

In the balanced equation

Number of the moles of electrons lost by the metal (M) = Number of the moles of electrons gained by the nonmetal (X)

Test Yourself

In the equation : $4Al + 3O_2 \longrightarrow 2Al_2O_3$, when aluminum atoms lose 12 mol of electrons, so oxygen atoms

ⓐ gain 4 mol of electrons

ⓑ gain 12 mol of electrons.

ⓒ lose 4 mol of electrons.

ⓓ lose 12 mol of electrons.

Idea of answering :

∵ No. of moles of the electrons lost by aluminum = ...

∴ No. of moles of the electrons gained by oxygen = ...

Answer : The correct choice is ... .

Worked Examples

1 Each of the following changes represents either an oxidation or a reduction reac[tion] except

ⓐ $CO_2 \longrightarrow CO$

ⓑ $ClO^- \longrightarrow ClO_3^{2-}$

ⓒ $N_2O_4 \longrightarrow NO_2$

ⓓ $V_2O_3 \longrightarrow V_2O_5$

Idea of answering :

ⓐ $\overset{?}{C}\overset{-2}{O_2} \longrightarrow \overset{?}{C}\overset{-2}{O}$

$C + (-2 \times 2) = 0$, $C = +4$; $C + (-2) = 0$, $C = +2$

$C = +4 \xrightarrow{\text{Reduction process}} C = +2$

∵ Carbon underwent a reduction process, as its oxidation no. decreased from +4 to +2

∴ The choice ⓐ is excluded.

ⓑ $(\overset{?}{Cl}\overset{-2}{O})^- \longrightarrow (\overset{?}{Cl}\overset{-2}{O_3})^{-}$

$Cl + (-2) = -1$, $Cl = +1$; $Cl + (-2 \times 3$ ... , $Cl = +4$

$Cl = +1 \xrightarrow{\text{Oxidation process}} Cl = +4$

∵ Chlorine underwent an oxidation pro[cess], as its oxidation no. increased from +1 ...

∴ The choice ⓑ is excluded.

ⓒ $\overset{?}{N_2}\overset{-2}{O_4} \longrightarrow \overset{?}{N}\overset{-2}{O_2}$

$2N + (-2 \times 4) = 0$, $2N = +8$, $N = +4$; $N + (-2 \times 2) = 0$, $N = +4$

$N = +4 \xrightarrow{\text{No change}} N = +4$

• Neither oxidation nor reduction occurred, because there is no change in the oxidation number of nitrogen.

Answer : The correct choice is ⓒ

Explain the type of change (oxidation or reduction) that occurred to each of iron and carbon in the following reaction

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

Answer

$\overset{-2}{Fe_2O_3} \longrightarrow \overset{0}{Fe}$

$2Fe + (-2 \times 3) = 0$

$2Fe = +6$

$Fe = +3$ $\qquad$ $Fe = 0$

$\underbrace{\qquad\qquad}_{\text{Reduction process}}$

Reduction process occurred to iron, where the oxidation number of iron decreased from +3 to 0

$\overset{-2}{CO} \longrightarrow \overset{-2}{CO_2}$

$C + (-2) = 0$ $\qquad$ $C + (-2 \times 2) = 0$

$C = +2$ $\qquad$ $C = +4$

$\underbrace{\qquad\qquad}_{\text{Oxidation process}}$

Oxidation process occurred to carbon where the oxidation number of carbon increased from +2 to +4

Explain the change (whether oxidation or reduction) that occurred to each of chromium and iron in the following reaction :

$$K_2Cr_2O_7 + 6FeCl_2 + 14HCl \longrightarrow 2KCl + 2CrCl_3 + 6FeCl_3 + 7H_2O$$

Answer :

$\overset{+1}{K_2}\overset{?}{Cr_2}\overset{-2}{O_7} \longrightarrow \overset{?}{Cr}\overset{-1}{Cl_3}$

$(+1 \times 2) + 2Cr + (-2 \times 7) = 0$ $\qquad$ $Cr + (-1 \times 3) = 0$

$2Cr = +12$

$Cr = +6$ $\qquad$ $Cr = +3$

$\underbrace{\qquad\qquad}_{\text{Reduction process}}$

Reduction process occurred to chromium, because the oxidation number of chromium decreased from +6 to +3

$\overset{?}{Fe}\overset{-1}{Cl_2} \longrightarrow \overset{?}{Fe}\overset{-1}{Cl_3}$

$Fe + (-1 \times 2) = 0$ $\qquad$ $Fe + (-1 \times 3) = 0$

$Fe = +2$ $\qquad$ $Fe = +3$

$\underbrace{\qquad\qquad}_{\text{Oxidation process}}$

Oxidation process occurred to iron, because the oxidation number of iron increased from +2 to +3

What are the oxidizing and the reducing agents

In the reaction : $2H_2S + SO_2 \longrightarrow 2H_2O + 3S$?

Choices	Oxidizing agent	Reducing agent
(a)	SO_2	S
(b)	H_2S	SO_2
(c)	S	H_2S
(b)	SO_2	H_2S

Idea of answering :

∵ Sulphur in H_2S underwent an oxidation process, as its oxidation number increased from –2 to 0

∴ H_2S is the reducing agent.

∴ The choices (a) and (b) are excluded.

$\overset{+1\ ?}{H_2S} \longrightarrow$

$(+1 \times 2) + S = 0$

$S = -2$

Oxidation

∵ Sulphur in SO_2 underwent a reduction process, as its oxidation number decreased from +4 to 0

∴ SO_2 is the oxidizing agent.

$\overset{?\ -2}{SO_2} \longrightarrow$

$S + (-2 \times 2) = 0$

$S = +4$ S =

Reduction

Answer : The correct choice is (d)

Deduce the values of "n" in the following reactions :

(1) $S^{6+} + ne^- \longrightarrow S^{2-}$

(2) $2Br^n - 2e^- \longrightarrow Br_2$

Answer :

(1) $6 + (n \times -1) = -2$, $6 - n = -2$ ∴ $n = +8$

(2) $2n - (2 \times -1) = 0$, $2n + 2 = 0$, $2n = -2$ ∴ $n = -1$

What is the total number of electrons in the anion $(SO_4)^{2-}$? [S = 16 , O = 8]

a) $48e^-$

b) $50e^-$

c) $46e^-$

d) $52e^-$

Idea of answering :

- **The traditional method :**

No. of electrons of the element atoms = No. of element atoms × No. of electrons in each atom

No. of electrons of sulphur atoms = $1 \times 16 = 16e^-$

No. of electrons of oxygen atoms = $4 \times 8 = 32e^-$

$\therefore$ Total no. of electrons of sulphur and oxygen atoms = $16 + 32 = 48e^-$

$\because$ The anion carries 2 negative charges (i.e. it gained 2 electrons).

$\therefore$ Total no. of electrons in the anion = $48 + 2 = 50e^-$

- **The oxidation number method :**

$\because$ Oxidation number of oxygen O = -2

Oxidation number of sulphate anion $(SO_4)^{2-} = -2$

$\therefore -2 = S + (4 \times -2)$

$S = -2 + 8 = +6$

$\therefore$ Oxidation number of sulphur S in this anion = +6

$\because$ No. of electrons of $S^{6+} = 16 - 6 = 10e^-$

No. of electrons of $O^{2-} = 8 + 2 = 10e^-$

$\therefore$ Total no. of electrons in the anion =

No. of electrons of S^{6+} + (4 × No. of electrons of O^{2-}) = $10 + (4 \times 10) = 50e^-$

Answer : The correct choice is b

Ready

Preliminary questions to remember the principal concepts in the lesson

Answer them yourself

1 Choose the correct answer for each of the following sentences :

(1) The oxidation number of hydrogen equals (–1) in ....

a. CaH_2

b. H_2O

c. H_2O_2

d. HCl

(2) During the electrolysis of all the following compounds, hydrogen gas evolves at the anode, except ....

a. H_2O

b. CaH_2

c. NaH

d. LiH

(3) The oxidation number of sodium in sodium peroxide Na_2O_2 equals ....

a. –2

b. –1

c. +1

d. +2

(4) What is the oxidation number of fluorine in OF_2 ?

a. –1

b. +1

c. +2

d. –2

(5) The oxidation number of phosphorus in phosphate ion $(PO_4)^{3-}$ is ....

a. +3

b. +5

c. +8

d. –3

(6) The summation of the oxidation numbers of both oxygen and hydrogen in H_2O equals ....

a. 0

b. –4

c. –2

d. +4

(7) The conversion of iron (III) ion into iron (II) ion is a(an) ....

a. excitation process.

b. oxidation process.

c. reduction process.

d. loss of electron process.

(8) Which of the following reactions represents an oxidation-reduction reaction ?

a. $CuO + H_2SO_4 \longrightarrow CuSO_4 + H_2O$

b. $CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$

c. $(Cr_2O_7)^{2-} + 3H_2S + 8H^+ \longrightarrow 2Cr^{3+} + 3S + 7H_2O$

d. $NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$

2 Calculate the oxidation number of :

(1) Hydrogen in : (a) KOH (b) KH	**(2) Oxygen in :** (a) KO_2 (b) Li_2O
(3) Chlorine in : (a) Cl_2 (b) $KClO_4$	**(4) Sulphur in :** (a) $NaHSO_4$ (b) $(SO_3)^{2-}$

Multiple choice questions

1 What is the compound in which nitrogen have two oxidation numbers ?

ⓐ $NaNO_3$
ⓑ NH_4NO_3
ⓒ NH_4Cl
ⓓ NH_2NH_2

2 Which of the atoms that have the following electronic configurations, can form the highest number of oxidation states in different compounds ?

ⓐ [Ar] , $3d^1$, $4s^2$
ⓑ [Ar] , $3d^2$, $4s^2$
ⓒ [Ar] , $3d^{10}$, $4s^2$
ⓓ [Ar] , $3d^5$, $4s^2$

3 What is the oxidation number of the transition metal in $Al_2(CrO_4)_3$?

ⓐ +3
ⓑ +5
ⓒ +6
ⓓ +7

4 What is the oxidation number of phosphorus in pyrophosphate ion $(P_2O_7)^{4-}$

ⓐ +3.5
ⓑ +5
ⓒ +7
ⓓ +10

5 What is the electronic configuration of manganese $[_{25}Mn]$ in $Mn_2(SO_4)_3$?

ⓐ [Ar] , $3d^6$
ⓑ [Ar] , $3d^4$
ⓒ [Ar] , $4s^2$, $3d^2$
ⓓ [Ar] , $4s^2$, $3d^5$

6 The electron configuration of oxygen ion in Na_2O_2 is ....

ⓐ $1s^2$, $2s^2$, $2p^6$
ⓑ $1s^2$, $2s^2$, $2p^4$
ⓒ $1s^2$, $2s^2$, $2p^3$
ⓓ $1s^2$, $2s^2$, $2p^5$

7 When aluminum is oxidized forming Al^{4+} ion, it loses the last electron from the sublevel ....

ⓐ $1s$
ⓑ $2s$
ⓒ $2p$
ⓓ $3s$

8 Which of the following elements is easier to be oxidized ?

ⓐ Sulphur.
ⓑ Magnesium.
ⓒ Boron.
ⓓ Argon.

9 Which of the following is the strongest oxidizing agent ?

ⓐ F_2
ⓑ Cl_2
ⓒ Br_2
ⓓ Cl^-

10 What is the symbol of the element which is the strongest reducing agent in the period that contains the element which has the highest electronegativity in the modern periodic table ?

ⓐ Li
ⓑ Na
ⓒ Ar
ⓓ K

11 When $(MnO_4)^-$ reacts and is converted to Mn^{2+}, $(MnO_4)^-$ is ....

ⓐ reduced, as the oxidation number of manganese increases.
ⓑ oxidized, as the oxidation number of manganese increases.
ⓒ reduced, as the oxidation number of manganese decreases.
ⓓ oxidized, as the oxidation number of manganese decreases.

12 All the following reactions are oxidation-reduction reactions, except ....

ⓐ $CH_4 + Br_2 \longrightarrow CH_3Br + HBr$
ⓑ $2Na + 2H_2O \longrightarrow 2NaOH + H_2$
ⓒ $3HNO_2 \longrightarrow HNO_3 + 2NO + H_2O$
ⓓ $CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O$

13 In each of the following conversions the oxidation number of nitrogen changes, except ....

ⓐ $NO_3^- \longrightarrow NO$
ⓑ $N_2O_4 \longrightarrow NO_3$
ⓒ $NH_3 \longrightarrow (NH_4)^+$
ⓓ $NO_2 \longrightarrow N_2O_5$

14 In which of the following changes an oxidation process occurs to vanadium V ?

ⓐ $VO_2 \longrightarrow V_2O_3$
ⓑ $V_2O_5 \longrightarrow VO_2$
ⓒ $V_2O_3 \longrightarrow VO$
ⓓ $V_2O_3 \longrightarrow V_2O_5$

15 In which of the following equations the underlined substance acts as a reducing agent

(a) $\underline{CaO} + H_2O \longrightarrow Ca(OH)_2$

(b) $\underline{CO_2} + C \longrightarrow 2CO$

(c) $\underline{CuO} + H_2 \longrightarrow Cu + H_2O$

(d) $3\underline{CO} + Fe_2O_3 \longrightarrow 2Fe + 3CO_2$

16 In the reaction : $ClO_3^- + Cl^- \longrightarrow Cl_2 + ClO_2$

Which of the following statements represents this reaction ?

(a) Oxygen is reduced and chlorine is oxidized.

(b) Oxygen is oxidized and chlorine is reduced.

(c) Chlorine is oxidized and reduced.

(d) Oxygen is oxidized and reduced.

17 The three following reactions take place during thunder storms :

- $N_2 + O_2 \longrightarrow 2NO$
- $2NO + O_2 \longrightarrow 2NO_2$
- $NO + O_3 \longrightarrow NO_2 + O_2$

Which of the following choices represents what happens to the molecules of the reactants through these reactions ?

Choices	N_2	NO	O_3
(a)	Oxidized	Oxidized	Oxidized
(b)	Oxidized	Oxidized	Reduced
(c)	Reduced	Reduced	Oxidized
(d)	Reduced	Reduced	Reduced

18 In the chemical reaction represented by the following chemical equation :

$$Ni_{(s)} + 2HCl_{(aq)} \longrightarrow NiCl_{2(aq)} + H_{2(g)}$$

What does happen to nickel Ni atom ?

(a) Loses $1e^-$

(b) Gains $1e^-$

(c) Loses $2e^-$

(d) Gains $2e^-$

19 In the following oxidation-reduction reaction :

$$2Cr^{3+}_{(aq)} + 3Cl_{2(aq)} + 7H_2O_{(l)} \longrightarrow Cr_2O^{2-}_{7(aq)} + 6Cl^-_{(aq)} + 14H^+_{(aq)}$$

Which of the following loses electrons ?

(a) Cl_2

(b) Cr^{3+}

(c) H_2O

(d) $Cr_2O_7^{2-}$

20 In the opposite redox reaction : $Fe^{3+} + Al \longrightarrow Fe + Al^{3+}$

The electrons transfer from ....

(a) $Fe^{3+} \longrightarrow Al$
(b) $Al \longrightarrow Fe^{3+}$
(c) $Fe \longrightarrow Fe^{3+}$
(d) $Al^{3+} \longrightarrow Al$

21 In the process represented by the reaction : $ClO^- \longrightarrow ClO_3^{2-}$

Which of the following about chlorine is correct ?

Choices	Electrons	Ionic size
(a)	It gains 3 electrons	Decreases
(b)	It gains 3 electrons	Increases
(c)	It loses 3 electrons	Decreases
(d)	It loses 3 electrons	Increases

22 Sulphur can act as an oxidizing agent and as a reducing agent.

What is the scientific explanation for that ?

(a) Because sulphur forms sulphur dioxide as well as calcium sulphide.
(b) Because sulphur is a nonmetal.
(c) Because the outermost level in sulphur contains 6 electrons, so it can gain 2 electrons or share its valence electrons with other atoms.
(d) Because sulphur dissolves in carbon sulphide as well as in alcohols.

23 When NO_2 reacts and is converted to N_2O_4

The oxidation number of nitrogen ....

(a) increases by 2
(b) increases by 4
(c) increases by 8
(d) does not change.

24 Nitric acid is prepared in industry according to the following sequence :

$$N_2 \longrightarrow NH_3 \longrightarrow NO \longrightarrow NO_2 \longrightarrow HNO_3$$

What is the correct arrangement of the oxidation numbers of nitrogen in these molecules ?

Choices	N_2	NH_3	NO	NO_2	HNO_3
(a)	0	−3	+2	+4	+5
(b)	0	−3	−2	+4	+5
(c)	−3	+3	+2	+4	+5
(d)	−3	+3	−2	−4	−5

25 The following equation represents an oxidation-reduction reaction :

$$4H_2SO_4 + 3H_2S + K_2Cr_2O_7 \longrightarrow 7H_2O + K_2SO_4 + 3S + Cr_2(SO_4)_3$$

What is the number of sulphur atoms which are exposed to an oxidation process in this equation ?

ⓐ 1
ⓑ 3
ⓒ 4
ⓓ 7

Questions marked by this mark their ideas are explained in the answers

26 The oxidation number of element (X) in most of its compounds is (–1) when it combines with element (Y), they form a compound its formula is Y_2X and the oxidation number of (X) in this compound is (+4)

What are the two elements (X) and (Y) ?

Choices	(X)	(Y)
ⓐ	F	H
ⓑ	Cl	Na
ⓒ	C	O
ⓓ	Cl	O

27 The table shows the first four ionization potentials of the elements (X) and (Y) :

Element	1st ionization potential	2nd ionization potential	3rd ionization potential	4th ionization potential
(X)	+590 kJ/mol	+1145 kJ/mol	+4912 kJ/mol	+6491 kJ/mol
(Y)	+1314 kJ/mol	+3388 kJ/mol	+5301 kJ/mol	+7469 kJ/mol

Which of the following describes the elements (X) and (Y) ?

On the combination of ....

ⓐ element (X) with hydrogen, the oxidation number of hydrogen is +1
ⓑ element (Y) with hydrogen, the oxidation number of hydrogen is –1
ⓒ element (Y) with element (X), element (X) is reduced.
ⓓ element (X) with element (Y), element (Y) acts as an oxidizing agent.

In the following equation, the coefficients W, X, Y, Z are whole numbers :

$$[W]ClO_3^- + [X]MnO_4^- + [Y]H^+ \longrightarrow [W]ClO_4^- + [X]MnO_2 + [Z]H_2O$$

which of the following represents the coefficients W, X and Y ?

Choices	(W)	(X)	(Y)
(a)	1	2	2
(b)	2	2	2
(c)	2	3	8
(d)	3	2	2

Essay questions

9 (BrO) ion is converted to $(BrO_3)^{2-}$ ion.

Is this conversion an oxidation or a reduction ? Explain.

10 Calculate the oxidation number of zinc in sodium zincate.

11 Determine the oxidizing agent and the reducing agent in the following reaction :

$$2H_2S + SO_2 \longrightarrow 2H_2O + 3S$$

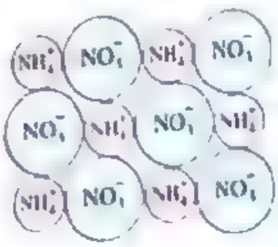
12 The following figure represents a section in the modern periodic table :

Which of the illustrated elements :

(1) Is characterized by several oxidation states, with mentioning them.

(2) Has an oxidation state −1 in the active metals hydrides.

13 The opposite figure : represents the surface of an ammonium nitrate crystal, determine the oxidation number of nitrogen in :



(1) The anion.

(2) The cation.

The table shows the quantum numbers of the last electron in the atom of each of 4 elements :

(1) Which of the elements shown in the table :

1. Reduces hydrogen upon combining with it.
2. Is the strongest oxidizing agent.

(2) What is the oxidation number of element (Z) when it combines with element (W) ?

Element	Quantum [illegible] the [illegible]
W	$n = 3 , l = 0 , m = 0$ [illegible]
X	$n = 2 , l = 1 , m =$ [illegible]
Y	$n = 3 , l = 1 , m = -1$ [illegible]
Z	$n = 3 , l = 1 , m =$ [illegible]

• Choose the correct answer for the questions 1 : 21 .

1 In the second period, on moving from lithium to fluorine,

ⓐ the atomic size decreases.

ⓑ the ionization potential decreases.

ⓒ the electronegativity decreases.

ⓓ the nuclear charge decreases.

2 The following table exhibits the electron configuration of six different elements :

[Kr], $4d^{10}$, $5s^2$	[Xe], $4f^9$, $6s^2$	[Kr], $5s^1$, $4d^{10}$, $5p^6$, $6s^1$
$1s^2$	[Xe], $6s^2$, $4f^{14}$, $5d^{10}$, $6p^6$, $7s^1$	[Xe], $4f^{14}$, $5d^0$, $6s^1$

What is the number of the elements which are located in s-block ?

ⓐ 2 ⓑ 4

ⓒ 5 ⓓ 6

3 In which of the following choices is the summation of the two oxidation numbers of manganese and nitrogen – each in its compound – the least ?

Choices	Manganese compound	Nitrogen compound
ⓐ	$MnCl_4$	N_2
ⓑ	$MnCO_3$	NO_2
ⓒ	K_2MnO_4	NH_4^+
ⓓ	$Mn(OH)_3$	NH_2OH

4 Which of the following statements is correct ?

ⓐ The element with the atomic number 80 is located in the 6^{th} period, group (1B)

ⓑ The element with the atomic number 38 is located in the 6^{th} period, group (2B)

ⓒ The element with the electronic configuration : [Xe], $4f^{14}$, $5d^5$, $6s^2$ is located in 6^{th} period, group (7B).

ⓓ The element with the electronic configuration : [Ar], $3d^{10}$, $4s^2$, $4p^4$ is located in 4^{th} period, group (6B).

5 What are the two metals whose oxides can react with both acids and alkalis ?

ⓐ Na , Zn ⓑ Mg , Al
ⓒ Mg , Be ⓓ Al , Zn

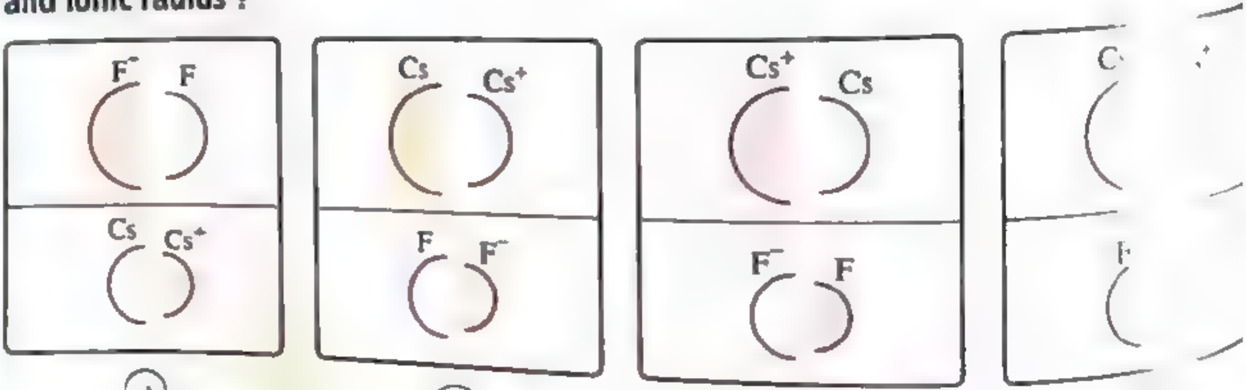
6 Which of the following represents the correct order of these acidic oxides according to the strength of acidity ?

ⓐ $SO_2 > P_2O_3 > SiO_2 > Al_2O_3$
ⓑ $P_2O_3 > SO_2 > SiO_2 > Al_2O_3$
ⓒ $P_2O_3 > Al_2O_3 > SO_2 > SiO_2$
ⓓ $Al_2O_3 > SiO_2 > P_2O_3 > SO_2$

7 Which of the following represents the proper ascending graduation of the electronegativities of these elements ?

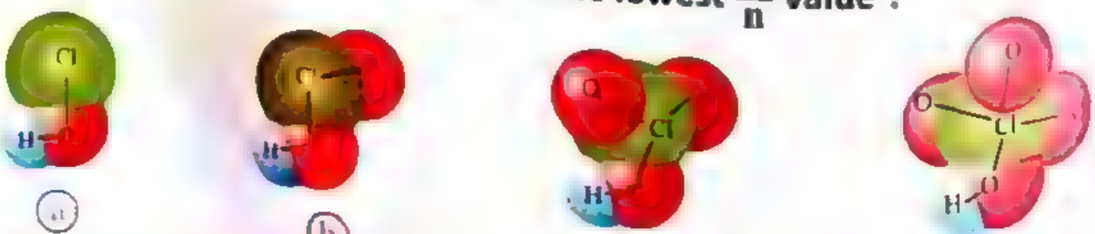
ⓐ S < P < N < O
ⓑ P < S < N < O
ⓒ N < O < P < S
ⓓ N < P < S < O

8 Which of the following represents the correct relation between the atomi... us and ionic radius ?



ⓐ ⓑ ⓒ ⓓ

9 Which of the following oxygenated acids has the lowest $\frac{m}{n}$ value ?



ⓐ ⓑ ⓒ ⓓ

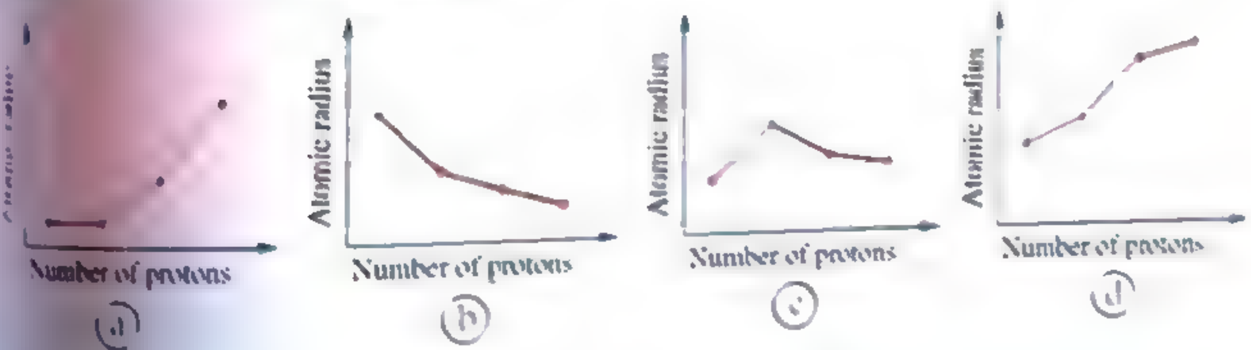
Which of the following statements is correct ?

- Lanthanum and actinium do not belong to lanthanides and actinides.
- The element whose atomic number is 31 is located in the third period.
- The electron configuration of $_{27}$Co does not follow the system : $ns^{1,2}, (n-1)d^{1:10}$
- All actinides are synthesized.

Element (X) is located in the fourth period, group (15) in the modern periodic table. Which of the following represents the electron configuration of the last energy level in its atom ?

- d orbitals are half filled and s orbital is completely filled.
- s orbital is completely filled and p orbitals are half filled.
- d orbitals are occupied by electrons and s orbital is half filled.
- p orbitals are half filled and s orbital is half filled.

Which of the following graphical figures represents the graduation of the atomic radii of the elements of group (1A) ?



The opposite table shows the first five ionization potentials of the element (X).

Ionization potential (kJ/mol)				
First	Second	Third	Fourth	Fifth
+738	+1451	+7733	+10541	+13629

What is the number of the group of the element (X) in the modern periodic table ?

- 1
- 2
- 13
- 14

14 What is the oxidizing agent in the reaction ...

(a) Cu

(b) Ag^+

(c) Cu^{++}

(d) Ag

15 Which of the following oxides react together when dissolved in water ?

(a) Al_2O_3 , ZnO

(b) Na_2O , MgO

(c) Na_2O , P_2O_5

(d) SO_3 , P_2O_5

16 In the reaction : $3NaClO \xrightarrow{\Delta} 2NaCl + NaClO_3$

Which of the following choices represents the oxidation numbers of chlorine in the three compounds ?

Choices	NaClO	NaCl	$NaClO_3$
(a)	−1	−1	+5
(b)	+1	−1	+5
(c)	+1	−1	+7
(d)	+2	+1	+7

17 The electronegativity of aluminum $_{13}Al$ is similar to the electronegativity of ....

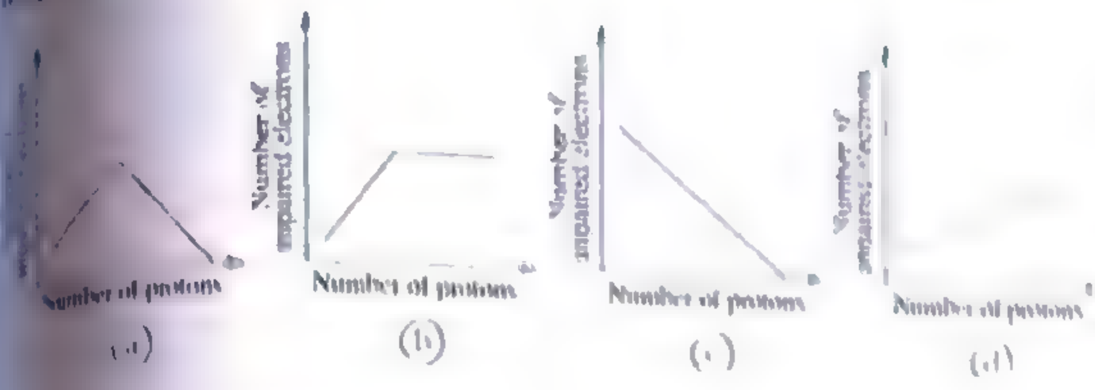
(a) barium $_{56}Ba$

(b) beryllium $_4Be$

(c) magnesium $_{12}Mg$

(d) strontium $_{38}Sr$

Which of the following graphical figures represents the number of the unpaired electrons in the orbitals of $3p$ sublevel in the elements of the third period in the periodic table ?



In the following equations :

(1) $Na_{(g)} \longrightarrow Na^{+}_{(g)} + e^{-}$ $\quad\quad \Delta H = w$

(2) $Na_{(g)} \longrightarrow Na^{2+}_{(g)} + 2e^{-}$ $\quad\quad \Delta H = x$

(3) $Na_{(s)} \longrightarrow Na_{(g)}$ $\quad\quad \Delta H = y$

(4) $Na_{(s)} \longrightarrow Na^{2+}_{(g)} + 2e^{-}$ $\quad\quad \Delta H = z$

Which of the following equations represents the second ionization potential of sodium ?

Equation (2) × Equation (1).

Equation (2) – Equation (1).

Equation (3) – Equation (1).

Equation (4) – Equation (3).

The electronic configuration : $[Xe]\ ,\ 6s^2\ ,\ 5d^{10}\ ,\ 4f^{14}\ ,\ 6p^3$ represents ....

an inner transition element.

a main transition element.

a representative element.

a noble element.

21 (1) : Number of protons in Mg^{2+} is higher than that in Al^{3+}

(2) : Number of neutrons in each of Mg^{2+} and Al^{3+} is higher than the number of protons in each of them.

(3) : The electronic configurations of Mg^{2+} and Al^{3+} are similar.

(4) : Numbers of neutrons in both of Mg^{2+} and Al^{3+} are equal.

Which of these statements represent $^{27}_{13}Al^{3+}$ and $^{26}_{12}Mg^{2+}$ ions ?

(a) (1) and (2) only.

(b) (1) and (3) only.

(c) (3) and (4) only.

(d) (2) , (3) and (4).

22 **The following table represents the four quantum numbers of the last electron in th atoms of two elements (X) and (Y) in the excited state :**

Quantum numbers	(n)	(l)	(m_l)	(m_s)
The electron of the atom of element (X)	3	1	0	$+\frac{1}{2}$
The electron of the atom of element (Y)	6	1	0	$\frac{1}{2}$

Which of the two elements when it becomes in its ground state, its electron w have four quantum numbers identical to those of the excited electron of the o element ? **Explain.**

....

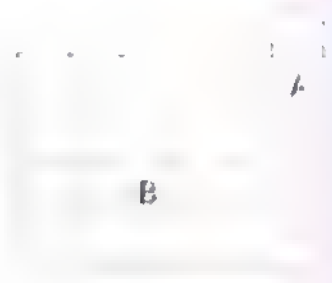
....

....

....

....

The opposite figure represents a section in the periodic table :



(1) **What** is the block of each of A and B ?

....

(2) **Write** the electronic configuration of each of the elements A and B according to the nearest noble gas.

....

....

1 mark

24 Two compounds HIO and $HClO_3$:

(1) **Which** of them is more acidic ? **Explain.**

....

....

....

....

(2) **Calculate** the oxidation number of each of iodine and chlorine in the two compounds.

....

....

2 marks

25 Write the electron configurations of two of the elements of the fourth period, where the sublevel *d* in each of them contains 5 unpaired electrons.

....

....

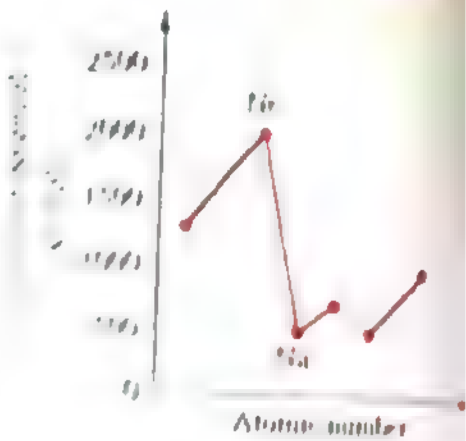
....

1 mark

26 What is meant by that the bond length in $NaCl = 2.79$ Å ?

27 The opposite figure represents the first ionization potentials of some elements of the second and the third periods.

Why is the first ionization potential of neon higher than that of sodium ?



GO

Open Book Exam Models

About the curriculum of the First Term

Answered

- Choose the correct answer for the following questions :

1 **The properties of the cathode rays differ from those of alpha rays in**

- that they can be observed through flashes.
- that they both move in straight lines.
- that they both are particles.
- the direction of their deflection in an electric field.

2 **Bohr's and Rutherford's models are similar in that ......**

- the electron can gain a quantum of energy.
- the electron can not be found within the regions between the energy levels.
- the electron orbits the nucleus in definite constant orbits.
- the electron is a negatively charged particle.

3 **Which of the following properties is not among those of the line spectrum ?**

- It consists of coloured lines separated by lighted areas.
- It arises from the return of the excited electron to its level.
- It is produced through heating the atoms of the elements in the state of gas or vapour.
- Each element has a characteristic line spectrum.

4 **The opposite figure shows the probabilities of finding the electron in the atom.**

The most accurate choice is .....

- B, C and D are consistent with Bohr's model.
- A, C and D are consistent with the modern atomic theory.
- B, C and D are consistent with the modern atomic theory.
- A, B and C are consistent with Bohr's model.

5 **Among the modifications of the wave mechanical theory on Rutherford's model is ......**

- that the nucleus of the atom is positively charged.
- that the atom is electrically neutral.
- that the atom is not solid but contains a vast space.
- the probability of finding the electron in the spaces around the nucleus.

The values of the sublevels of a principal energy level are up to 2

This principal level is

(a) [illegible] (b) N

(c) L (d) M

The electron configuration of an atom ends with the sublevel $4d^2$, the number of the orbitals which are occupied by electrons in the principal level $n = 4$ is

(a) 7 (b) 4

(c) 6 (d) 5

If $l = 2$, then the values of m_l and m_s of the first electron in the sublevel are

(a) $m_l = +2$, $m_s = +\frac{1}{2}$

(b) $m_l = -1$, $m_s = -\frac{1}{2}$

(c) $m_l = -2$, $m_s = +\frac{1}{2}$

(d) $m_l = +1$, $m_s = +\frac{1}{2}$

Element	[illegible]	$_{11}B$
First ionization potential (kJ/mol)	[illegible]	+495
Second ionization potential (kJ/mol)	+1451	+4558

The second ionization potential of element (B) is much higher than the second ionization potential of element (A), this is attributed to ....

(a) losing 2 electrons from the principal level L in (B).

(b) breaking the principal level L in (B) and the increase of the positive charge.

(c) breaking the principal level L in (A) and the increase of the positive charge.

(d) losing 2 electrons from the principal level M in (A).

4 elements are located in one group starting from the second period in the periodic table, so the electron affinity of the element whose electron configuration is $1s^2, 2s^2, 2p^6, 3s^1$ equals

(a) 53 kJ/mol (b) −60 kJ/mol

(c) −48 kJ/mol (d) −47 kJ/mol

11 The opposite table shows the electronic configurations of some elements, the element which has the highest electronegativity is ....

Element	Electronic configuration
X	$[_{10}Ne] : 3s^2 , 3p^5$
Y	$[_{10}Ne] : 3s^2 , 3p^2$
Z	$[_{18}Ar] : 4s^2 , 3d^{10} , 4p^5$
R	$[_{36}Kr] : 5s^2 , 4d^{10} , 5p^5$

ⓐ Y

ⓑ X

ⓒ R

ⓓ Z

12 The opposite table shows the quantum numbers of the last electron in the atoms of some elements.
Which of these elements is electronegative ?

Element	Quantum numbers
X	$n = 3 , l = 0 , m_l = 0 , m_s = +\frac{1}{2}$
Y	$n = 2 , l = 1 , m_l = +1 , m_s = -\frac{1}{2}$
Z	$n = 2 , l = 1 , m_l = -1 , m_s = -\frac{1}{2}$
R	$n = 3 , l = 0 , m_l = 0 , m_s = -\frac{1}{2}$

ⓐ Y

ⓑ X

ⓒ R

ⓓ Z

13 The ion X^{3+} electronic configuration ends with $6s^0 , 4f^{14} , 5d^8$
This means that element (X) is located in the group ....

ⓐ 8 ⓑ 10

ⓒ 11 ⓓ 9

14 The opposite table shows the outer electron configurations of some elements.
Which of the following is correct ?

Element	The outer electron configuration
A	$4s^1$
B	$3p^5$
C	$4p^5$

ⓐ HC is more acidic , and (A) has the largest radius.

ⓑ HB is more acidic , and (C) has the largest radius.

ⓒ HC is more basic, and (B) has the smallest radius.

ⓓ HB is more basic, and (A) has the smallest radius.

... same group their radii are estimated in angstroms.

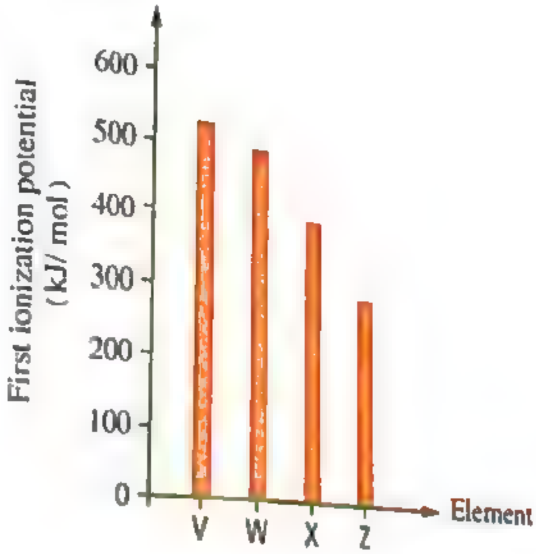
A	B	C	D
1.96	2.27	1.52	2.48

Which of the following is correct ?

(a) Element (C) has lower electron affinity than element (A).
(b) Element (A) has lower electronegativity than element (B).
(c) Element (D) has higher electronegativity than element (C).
(d) Element (B) has higher ionization potential than element (D).

16 Assisted by the opposite diagram which shows the values of the first ionization potentials of elements of the same group in the periodic table.

The element with the highest metallic property is ....



(a) X
(b) Z
(c) V
(d) W

17 The opposite table shows the electronic configuration of the last sublevel in some elements.

Element	A	B	C	D
The electrons of the last sublevel	$3p^1$	$3p^5$	$3p^3$	$3p^4$

Which of the following is correct ?

(a) (B) is a nonmetal and its electron affinity is high.
(b) (C) is a metal and its electron affinity is high.
(c) (A) is a nonmetal and its electron affinity is low.
(d) (D) is a metal and its electron affinity is low.

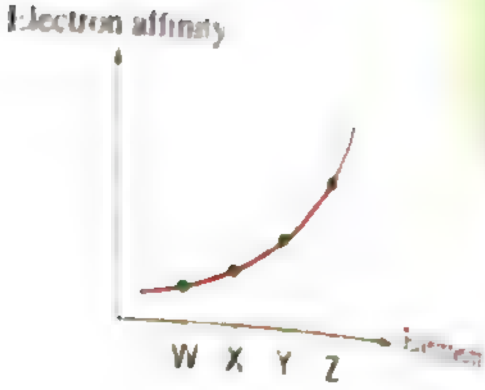
18 According to the equation : $X + e^- \longrightarrow X^- +$ High energy

Among the properties of element (X) that ....

(a) its oxide is amphoteric, and its ionization potential is high.
(b) its oxide is basic, and its ionization potential is high.
(c) its oxide is acidic, and its ionization potential is high.
(d) its oxide is acidic, and its ionization potential is low.

19 The opposite curve shows the graduation in the value of electron affinity of 4 elements in the third period (not in successive groups).

The correct order of the oxides of these elements relative to the acidic property is ....



ⓐ Z < Y < X < W

ⓑ X < Y < Z < W

ⓒ Z < W < X < Y

ⓓ W < X < Y < Z

20 You have the element (X) which is a representative element, and their probable ionization potentials are :

- $X \longrightarrow X^{+} + e^{-}$, $\Delta H = +500$ kJ/mol
- $X^{+} \longrightarrow X^{+2} + e^{-}$, $\Delta H = +675$ kJ/mol
- $X^{+2} \longrightarrow X^{+3} + e^{-}$, $\Delta H = +8780$ kJ/mol

Then, the element which precedes it in the same period is located in ....

ⓐ the first group A

ⓑ the second group A

ⓒ the fourth group A

ⓓ the third group A

21 Three representative elements X , Y and Z are located in one period and three different groups,

the formula of the oxide of each of them is : X_2O , YO_3 and ZO_2

The correct order according to the atomic radius of each of them is ....

Z > X > Y

X > Z > Y

X > Y > Z

Z > Y > X

Choose the correct answer for the following questions :

1 In the equation : $HCl_{(aq)} + HNO_{3(aq)} \longrightarrow NO_{2(g)} + \frac{1}{2}Cl_{2(g)} + H_2O_{(l)}$

Which of the following represents the previous reaction ?

(a) Nitrogen undergoes oxidation process.
(b) HNO_3 is the reducing agent.
(c) Chlorine undergoes reduction process.
(d) HCl is the reducing agent.

2 In the equation : $2FeCl_{3(aq)} + H_2S_{(aq)} \longrightarrow 2HCl_{(aq)} + 2FeCl_{2(aq)} + S_{(s)}$

Which of the following represents the previous reaction ?

(a) $FeCl_3$ is the oxidizing agent.
(b) A reduction process occurs to sulphur.
(c) H_2S is the oxidizing agent.
(d) An oxidation process occurs to iron.

3 **Three different elements, their radii are ordered as follows : X > Z > Y, these elements form the following acids : HXO, H_4YO_4, H_2ZO_2**

What is the correct ascending order of the strengths of these acids ?

(a) $H_4YO_4 < H_2ZO_2 < HXO$
(b) $H_2ZO_2 < H_4YO_4 < HXO$
(c) $H_2ZO_2 < HXO < H_4YO_4$
(d) $HXO < H_2ZO_2 < H_4YO_4$

4 **In the compound $C(OH)_4$, the attraction between (O , C) is equal to the attraction between (O , H), so this compound is ionized ....**

(a) in water as a salt.
(b) according to the type of the medium.
(c) in basic medium as a base.
(d) in acidic medium as an acid.

5 **In helium atom $_2He$, ...**

(a) the values of the spin quantum number are similar.
(b) $m_l = 1$
(c) the values of the spin quantum number are different.
(d) $m_l = -1$

6 The electronic configuration of the element (X) ends as follows : ns^1 , $(n-1)d^5$, and its electrons are distributed in 5 principal levels.

What is the atomic number of this element ?

ⓐ 29 ⓑ 24

ⓒ 47 ⓓ 42

7 Sr element is located in the fifth period, group (2A) in the modern periodic table.

Which of the following represents the electronic configuration of its ion ?

ⓐ [Ar] , $4s^2$, $3d^{10}$, $4p^6$ ⓑ [Ar] , $4s^2$

ⓒ [Kr] , $5s^2$, $4d^{10}$, $5p^4$ ⓓ [Kr] , $5s^2$

8 In terms of the opposite table,

if the length of the bond (C – Br) in CBr_4 = 1.91 Å

What is the length of the bond in CF_4 ?

Bond	F – F	Br – Br
Bond length	1.28 Å	2.28 Å

ⓐ 1.14 Å ⓑ 1.41 Å

ⓒ 0.77 Å ⓓ 0.64 Å

9 Four ions : $_{19}M^+$, $_4Z^{2+}$, $_{12}Y^{2+}$, $_{37}X^+$

What is the correct ascending order of their atomic radii ?

ⓐ Z < Y < X < M ⓑ Y < Z < M < X

ⓒ X < M < Y < Z ⓓ Z < Y < M < X

10 Which of the following choices is correct for the elements $_{19}X$ and $_{17}Y$?

ⓐ It is easier to reduce (X) than (Y). ⓑ It is easier to oxidize (Y) than (X).

ⓒ Both (X) and (Y) can be easily reduced. ⓓ It is easier to oxidize (X) than (Y).

11 The opposite table shows some properties of the elements (X) and (Y) which are located in the second period in the periodic table.

Which of the following statements is correct ?

Property	(X)	(Y)
Electron affinity	Low	High
Ionization potential	Low	High
Oxidation number	+3	–2

ⓐ Element (Y) is located in group (6A).

ⓑ Element (X) is located in group (2A).

ⓒ Element (X) is located in group (6A).

ⓓ Element (Y) is located in group (2A).

12 **The element whose last principal energy level (n = 3) contains 6 electrons forms ... ...**

ⓐ an amphoteric oxide.
ⓑ an acidic oxide
ⓒ a neutral oxide.
ⓓ a basic oxide

13 **The highest amount of energy is released when the excited electron of hydrogen atom transfers from ....**

ⓐ the orbit M to the orbit L, and the location of this electron can be determined
ⓑ the orbit N to the orbit M, and neither the location nor the speed of this electron can be determined precisely.
ⓒ the orbit L to the orbit K, and this electron has a dual nature.
ⓓ the orbit L to the orbit K, and both the location and the speed of this electron can be determined precisely.

14 **Element (X) is located in the group (4A).**
Which of the following its electron affinity is the highest ?

ⓐ X^- ⓑ X ⓒ X^+ ⓓ X^{2-}

15 **On comparing the properties of the elements of the group whose electronic configuration ends with ns^1 to the properties of the other elements, it is noticed that ....**

ⓐ their oxides are basic and their electron affinities are high.
ⓑ their oxides are acidic and their electron affinities are low.
ⓒ their oxides are basic and their electron affinities are low.
ⓓ their oxides are amphoteric and their electron affinities are high.

16 **What are the values of both principal and magnetic quantum numbers of the penultimate electron in sodium atom $^{23}_{11}Na$?**

ⓐ $n = 3$, $m_l = +2$
ⓑ $n = 3$, $m_l = -1$
ⓒ $n = 2$, $m_l = +1$
ⓓ $n = 2$, $m_l = -2$

17 **The opposite table shows the radii of four different atoms. Which element among these elements has the highest electronegativity ?**

Element	A	B	C	D
Atomic radius	1.34 Å	2.11 Å	0.73 Å	1.74 Å

ⓐ A
ⓑ B
ⓒ C
ⓓ D

18. The weakest metal in the group (IIA) in the periodic table is located in the ....

(a) sixth period.
(b) fifth period.
(c) seventh period.
(d) second period.

19. What is the type of the elements in which the electron configuration ends with $ns^{1:2}$, $np^{1:5}$?

(a) Representative.
(b) Main transition.
(c) Inner transition.
(d) Noble.

20. In the equation : $MOH \rightleftharpoons MO^{-} + H^{+}$

If the values presented in the following choices represent the first ionization potentials of the first four elements in the same period «with no particular order». What is the value of the first ionization potential of (M) ?

(a) +580 kJ/mol
(b) +1400 kJ/mol
(c) +780 kJ/mol
(d) +520 kJ/mol

21. The probability of the presence of the electron around the nucleus is represented by ....

(a) the orbital and the electron cloud.
(b) the quantum and the line spectrum.
(c) the line spectrum and the orbital.
(d) the quantum and the electron cloud.

22. Dalton and Thomson agreed on that carbon atom ....

(a) has no spaces within it.
(b) is electrically neutral.
(c) contains negative electrons.
(d) is a homogenous sphere.

23. The modern atomic theory agrees with Rutherford's atomic model on ....

(a) that the atom is not solid.
(b) that the electrons have wave properties.
(c) that it is impossible to determine both the location and the speed of the electron together precisely.
(d) the system of the revolving of the electrons around the nucleus.

24 The opposite table shows the ionization potentials of three metals in the same period in the modern periodic table.
What is the proper graduation of the metallic character of these elements ?

Element	A	B	C
Ionization potential (kJ/mol)	2800	1500	700

ⓐ B < C < A
ⓑ A < C < B
ⓒ C < B < A
ⓓ A < B < C

25 Three elements **X** , **Y** and **Z**, their electronic configurations end with ns^1.
and the values of their electron affinities are ordered as follows : Z > Y > X
What is the correct order of graduation of their metallic character ?

ⓐ Y < Z < X
ⓑ Z < X < Y
ⓒ Y < X < Z
ⓓ Z < Y < X

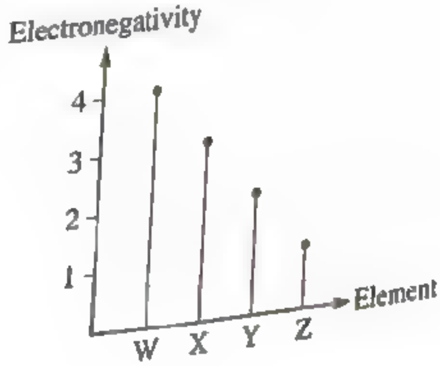
26 According to Hund's rule and Pauli's exclusion principle, the last two electrons which have the highest energy in the atom of the element $_{26}X$ are different in both quantum numbers ....

ⓐ ℓ and m_ℓ
ⓑ n and m_ℓ
ⓒ m_s and ℓ
ⓓ m_s and m_ℓ

27 Bohr's atomic model differs from that of Rutherford.
What is the postulate in Bohr's model which clarifies this difference ?

ⓐ The electron displays a line spectrum when it loses a quantum.
ⓑ The electron is a negatively charged material particle.
ⓒ The electron does not display a line spectrum when it loses a quantum.
ⓓ The electron revolves around the nucleus in certain orbits.

28 In the opposite graphical figure :
Which of these elements has lower electron affinity ?



ⓐ X
ⓑ Y
ⓒ Z
ⓓ W

29 What is the symbol of the energy level which contains s , p and d sublevels only ?

(a) L
(b) M
(c) N
(d) K

30 The first ionization potential of fluorine ($_9F$) is higher than that of oxygen ($_8O$) because

(a) number of energy levels in fluorine > number of energy levels in oxygen.
(b) number of energy levels in fluorine < number of energy levels in oxygen.
(c) atomic radius of fluorine > atomic radius of oxygen.
(d) atomic radius of fluorine < atomic radius of oxygen.

31 What happens when sodium hydroxide solution is added to aluminum hydroxide ?

(a) They don't react together, because they are both acids.
(b) $Al(OH)_3$ reacts as a base.
(c) They don't react together, because they are both bases.
(d) $Al(OH)_3$ reacts as an acid.

32 The electronic configuration of the ion of a trivalent metal is [Ar]. What is the type of this metal ?

(a) Main transition.
(b) Inner transition.
(c) Inert.
(d) Representative.

33 Which of the following statements represents the ionic compound which has the formula Y_2X ?

(a) (Y) is a nonmetal, (X) is a metal.
(b) (Y) is a nonmetal, (X) is a metalloid.
(c) (Y) is located in group (1A), (X) is located in group (6A).
(d) (Y) is located in group (6A), (X) is located in group (1A).

34 If the ions A^{2+} , B^{2-} are of two elements in the same period. Which of the following choices represents a comparison between the electronegativities of the two elements of these ions ?

(a) A < B
(b) A ≥ B
(c) A > B
(d) A = B

35 **What is the sublevel in which the last electron has the two quantum numbers ($n = 2$, $l = 0$) ?**

(a) $2s$ (b) $2p$

(c) $1s$ (d) $3p$

36 **The orbitals of the same sublevel are different in ....**

(a) the distance from the nucleus. (b) the magnetic quantum number.

(c) shape and size. (d) the subsidiary quantum number.

37 **What is the number of orbitals occupied by electrons in an atom in which $3p$ sublevel is half filled with electrons ?**

(a) 6 (b) 7

(c) 8 (d) 9

38 **When an electron transfers from the level K to the level L, it gains one quantum, and when it transfers from K to N, it gains ....**

(a) 0.5 quantum. (b) 1 quantum.

(c) 2 quanta. (d) 3 quanta.

39 **Among Heisenberg's modifications of Bohr's atomic model ....**

(a) it is difficult to determine both the location and the speed of the electron together around the nucleus precisely.

(b) the space regions between energy levels are not forbidden for the electrons.

(c) the electron is a material particle with wave properties.

(d) both the location and the speed of the electron can be determined precisely.

- Choose the correct answer for the following questions :

1. The opposite table shows the atomic radii of four elements in the same group in the periodic table estimated in angstroms.

Element	(A)	(B)	(C)	(D)
Atomic radius (Å)	1.96	2.27	1.52	2.48

Which of the following is correct ?

(a) Element (A) has lower electronegativity than that of element (B).
(b) Element (D) has higher electronegativity than that of element (C).
(c) Element (C) has lower electron affinity than that of element (A).
(d) Element (B) has higher ionization potential than that of element (D).

2. Bohr's atomic model is distinct from that of Rutherford in that the electrons in Bohr's model ....

(a) revolve in certain orbitals.
(b) ...ve in definite constant energy levels.
(c) revolve in high speed.
(d) ... around the nucleus.

3. If the electron gains an amount of energy ... eV to transfer from the energy level K to L, so to transfer from the energy level M to L it may ....

(a) lose an amount of energy equals 1.89 eV
(b) gain an amount of energy equals 1.89 eV
(c) lose an amount of energy equals 10.2 eV
(d) gain an amount of energy equals 10.2 eV

4. The second and third ionization potentials of the element (X) are represented by the following equations :

- $X^{+}_{(g)} \longrightarrow X^{2+}_{(g)} + e^-$ $\Delta H = +1450$ kJ/mol
- $X^{2+}_{(g)} \longrightarrow X^{3+}_{(g)} + e^-$ $\Delta H = +7730$ kJ/mol

It is concluded from these two equations that the element (X) compared to the element which precedes it in the same period is ....

(a) a nonmetal with lower ionization potential
(b) a nonmetal with higher ionization potential
(c) a metal with lower ionization potential
(d) a metal with higher ionization potential

5 Two elements (X) and (Y) are located in the same period, their radii are (0.157 Å) and (1.04 Å).

It is possible when they combine chemically that

(a) element (X) undergoes oxidation and element (Y) undergoes reduction

(b) element (X) and element (Y) both undergo oxidation.

(c) element (X) undergoes reduction and element (Y) undergoes oxidation

(d) neither element (X) nor element (Y) undergoes reduction.

6 What is the drawback of Bohr's model which was modified by the modern atomic theory ?

(a) The electron has wave nature only.

(b) The electron is just a negatively charged particle.

(c) The electron has dual nature.

(d) The electron revolves around the nucleus in an electron cloud.

7 The opposite table shows the electronic configurations of the atoms and ions of some elements.

Which of the following choices represents the correct graduation of the electronegativities of these elements ?

Atom or ion	Electronic configuration
A^{1-}	[Ne]
B^{2-}	[Ne]
C	[Ar], $4s^1$
D	[Ne], $3s^1$

(a) A > B > D > C

(b) B > C > A > D

(c) D > C > B > A

(d) A > D > C > B

8 Each of hydrogen and helium contains one energy level.

Which of the following describes the two elements ?

(a) The two elements are different in their line spectra.

(b) The two elements are equal in the number of electrons in each of them.

(c) The two elements are different in the principal quantum number of their valence electrons.

(d) The two elements are similar in their line spectra.

9 By applying the wave mechanical equation to the last electron in sodium atom $_{11}Na$
it is found that

(a) it is possible to determine its location precisely in the energy level M

(b) it moves back and forth from the nucleus within the energy level M

(c) its energy is lower than that of the electrons of the energy level L

(d) it transfers to the energy level L after losing a quantum.

10 To obtain the hydrogen atom visible spectrum of an electron which has been excited to the third energy level M, this electron must

(a) lose a quantum lower than that gained

(b) lose a quantum which is gained.

(c) gain a quantum.

(d) lose a quantum higher than that gained.

11 The electronic configuration of the element (Z) ends with $3p^1$ sublevel.
Which of the following choices represents the element (Z) relative to the elements which precede it in the same period ?

(a) A nonmetal with high electron affinity

(b) A nonmetal with low electron affinity

(c) A metal with high electron affinity

(d) A metal with low electron affinity.

12 The electron configuration of element (X) ends with the sublevels : $5s^2, 4d^{10}, 5p^5$
Which of the following choices represents the element (X) relative to the elements which precede it in the same period ?

(a) Its oxide is basic and its ionization potential is small.

(b) Its oxide is amphoteric and its ionization potential is high.

(c) Its oxide is acidic and its ionization potential is high.

(d) Its oxide is acidic and its ionization potential is small.

Choose the correct answer for the questions 1 : 21 .

21 marks

1. Three consecutive elements X , Y and Z in the periodic table, if the first element X is a noble gas.
What is the symbol of the ion of Z ?

ⓐ Z^{2-}
ⓑ Z^{2+}
ⓒ Z^{-}
ⓓ Z^{+}

2. Here are 4 hypothetical symbols for four elements ions : (A^{2+} / B^{-} / C^{+} / D^{2+}).
Which of the following statements represents all these ions ?

ⓐ The number of electrons in each of them is higher than that of the protons.
ⓑ Their nuclei contain the same number of neutrons.
ⓒ Their nuclei contain the same number of protons.
ⓓ The electronic configuration of each of them is similar to that of the nearest inert gas.

3. Element (X) burns in air forming white powder which when dissolved in water, it forms a solution turns the red litmus paper into blue.
What is the probable name of this element ?

ⓐ Sulphur.
ⓑ Iodine.
ⓒ Carbon.
ⓓ Magnesium.

4. In which of the following ions the electron cloud has the largest size ?

ⓐ S^{2-}
ⓑ Al^{3+}
ⓒ Be^{2+}
ⓓ N^{3-}

5. What is the number of electrons lost or gained by nitrogen atom in this conversion : $NO_2 \longrightarrow N_2O_3$?

ⓐ It loses one electron.
ⓑ It loses two electrons.
ⓒ It gains one electron.
ⓓ It gains two electrons.

6 Which of the following is incompatible with aufbau principle ?

ⓐ [↑↓] [↑ | ↑ | ↑]

ⓑ [↑↓] [↑↓ | ↑↓ | ↑]

ⓒ [↑] [↑↓ | ↑ | ↓]

ⓓ [↑↓ | ↑ | ↑]

7 Which of the following represents both the location and the block of the element whose atomic number is 24 ?

Choices	Period	Group	Block
ⓐ	6	4B	d
ⓑ	4	6B	d
ⓒ	6	4B	p
ⓓ	4	6B	p

8 What is the number of the elements which may form compounds but with great difficulty in the fourth period in the periodic table ?

ⓐ 1 ⓑ 2 ⓒ 3 ⓓ 4

9 What is the number of the elements in which the orbitals of *4d* sublevel contain one single (unpaired) electron or more in the ground state ?

ⓐ 7 ⓑ 8

ⓒ 9 ⓓ 10

10 Which of the following choices represents the electronic configuration of the atom which has higher electron affinity ?

ⓐ [Ne], $3s^2$, $3p^5$ ⓑ [Ne], $3s^2$, $3p^2$

ⓒ [Ne], $3s^2$, $3p^6$, $3d^5$, $4s^1$ ⓓ [Ne], $3s^2$, $3p^4$

11 Which of the following elements has the highest electronegativity ?

ⓐ $_{13}Al$ ⓑ $_{14}Si$

ⓒ $_{16}S$ ⓓ $_{34}Se$

12 Which of the following elements has the lowest first ionization energy ?

ⓐ $_{5}B$ ⓑ $_{6}C$

ⓒ $_{13}Al$ ⓓ $_{14}Si$

13 Which choice does represent the correct graduation in increasing the metallic property ?

ⓐ $_{14}Si < _{15}P < _{16}S$

ⓑ $_{33}As < _{15}P < _{7}N$

ⓒ $_{13}Al < _{32}Ge < _{51}Sb$

ⓓ $_{35}Br < _{34}Se < _{33}As$

14 Two ions (X^-) and (Y^+), both have the same electron configuration [Ar]. Which of the following statements represents the two elements of these ions ?

ⓐ The atomic radius of element (X) equals half that of element (Y).

ⓑ The electronegativity of element (X) equals that of element (Y).

ⓒ The first ionization potential of element (X) is lower than that of element (Y).

ⓓ The electron affinity of element (Y) is lower than that of element (X).

15 Which of the following transitions in an atom of hydrogen produces a photon with the highest energy ?

ⓐ $(n = 3) \longrightarrow (n = 1)$

ⓑ $(n = 5) \longrightarrow (n = 3)$

ⓒ $(n = 12) \longrightarrow (n = 10)$

ⓓ $(n = 22) \longrightarrow (n = 20)$

16 Which of the following represents an electron configuration of an excited atom ?

ⓐ $1s^2, 2s^2, 2p^1$

ⓑ $1s^2, 2s^2, 2p^2$

ⓒ $1s^2, 2s^2, 2p^2, 3s^1$

ⓓ $1s^2, 2s^2, 2p^5$

17 In the reaction : $ClO_3^- + 5Cl^- + 6H^+ \longrightarrow 3Cl_2 + 3H_2O$

What are the oxidizing and the reducing agents ?

Choices	Oxidizing agent	Reducing agent
ⓐ	Cl^-	ClO_3^-
ⓑ	ClO_3^-	Cl^-
ⓒ	ClO_3^-	H^+
ⓓ	Cl^-	H^+

18 **Which of the following elements atoms in its ground state could have an electron with the quantum numbers : $(n = 3, l = 2, m_l = 0, m_s = +\frac{1}{2})$?**

ⓐ $_{11}Na$ ⓑ $_{12}Mg$

ⓒ $_{15}P$ ⓓ $_{23}V$

19 **6 g of carbon react completely with 16 g of oxygen gas to form 22 g of CO_2 What is the mass of CO_2 which is produced from a mixture formed of 24 g of carbon with 100 g of oxygen gas ?**

ⓐ 40 g ⓑ 44 g

ⓒ 88 g ⓓ 112 g

20 **All the following are deflected by the effect of the charged plates, except ....**

ⓐ hydrogen atoms.

ⓑ cathode rays.

ⓒ alpha particles.

ⓓ protons.

21 **What is the name of the halogen which is located in the third period in the periodic table ?**

ⓐ Chlorine $_{17}Cl$

ⓑ Iodine $_{53}I$

ⓒ Bromine $_{35}Br$

ⓓ Astatine $_{85}At$

22 **Deduce with explanation** the oxidation number of the representative element whose last electron has the quantum numbers : $(l = 0, m_s = -\frac{1}{2})$.

....

....

....

....

....

2 marks

23 The opposite table shows the quantum numbers of two different electrons in the same atom. **Which of them has higher energy ? Explain.**

Quantum numbers	(n)	(ℓ)	(m_ℓ)	(m_s)
Electron (X)	4	3	0	$+\frac{1}{2}$
Electron (Y)	6	0	0	$+\frac{1}{2}$

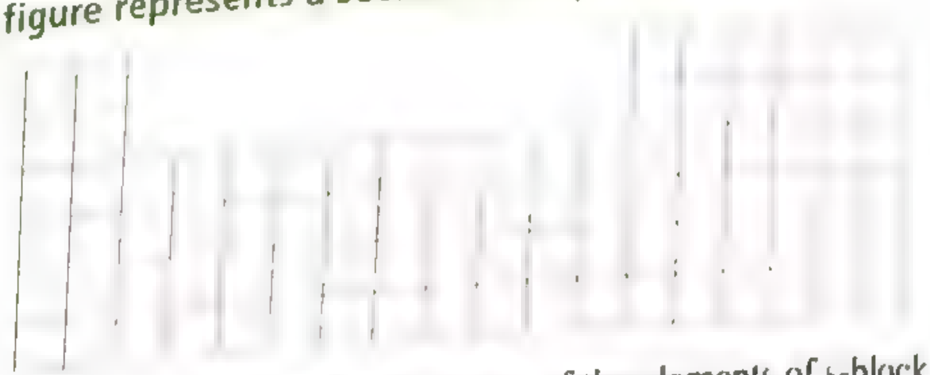
....

....

....

2 marks

24 The following figure represents a section in the periodic table :



(1) **Calculate** the difference between the number of the elements of s-block and the number of the elements of p-block.

....

....

(2) **What** is the missing block in the table ?

....

2 marks

25 Which of the following graphical figures represents the graduation of the basic property of the oxides of the elements of the third period in the periodic table ?

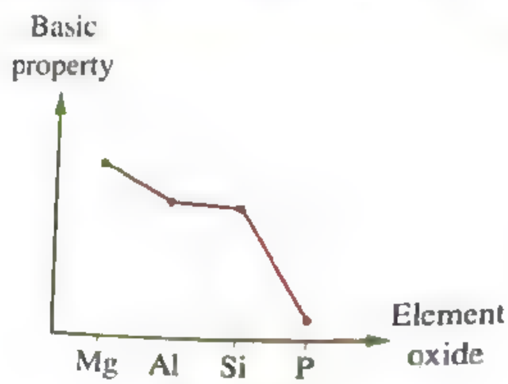


Figure (1)

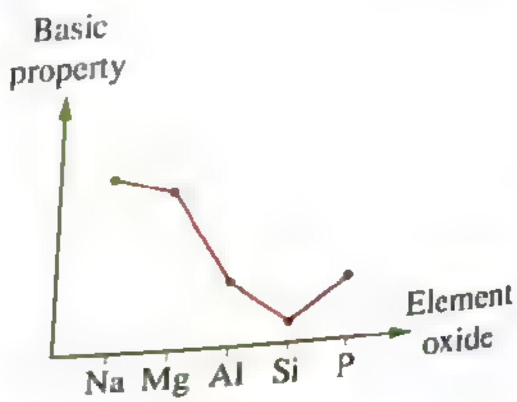


Figure (2)

1 mark

26 **What is the number of each of the completely filled orbitals and the partially occupied by electrons in the gaseous state of the atom of vanadium element $_{23}V$ in its ground state ?**

....

....

....

....

1 mark

27 **Complete the four quantum numbers of the last electron in the element (Y), knowing that it follows the element (X) in the same period in the periodic table :**

Quantum numbers	(n)	(l)	(m_l)	(m_s)
The element (X)	3	2	+2	$-\frac{1}{2}$
The element (Y)			....	....

1 mark

• Choose the correct answer for the questions 1 : 21 .

21 marks

1 What is the number of the inner transition elements in both fourth and fifth periods in the periodic table ?

(a) Zero (b) 14 (c) 24 (d) 28

2 If aufbau principle is disregarded in distributing the electrons of the elements. $_{20}Ca$ would be located in ....

(a) s-block. (b) p-block. (c) d-block. (d) f-block.

3 What is the atomic number of the element in which the orbitals of *4p* sublevel contain the highest possible number of single electrons ?

(a) 23 (b) 26
(c) 33 (d) 35

4 Which of the following elements has the highest ionization potential ?

(a) Ne (b) He
(c) Be (d) Te

5 In Rutherford's experiment, upon shooting a beam of ....

(a) beta particles on gold foil, it is absorbed.
(b) gamma rays on gold foil, electrons are liberated from its surface.
(c) helium atoms on gold foil, most of them are scattered.
(d) helium nuclei on gold foil, some of them are scattered.

6 Understanding the movement of the electrons in the atom is based on all the following, except ....

(a) Rutherford's experiment which proved the presence of the nucleus.
(b) Thomson's atomic model.
(c) Bohr's model of atom which is based on hydrogen atom.
(d) Schrödinger's equation which introduced the concept of the orbital.

7. The weakest halogen acid is ....

(a) HBr (b) HI (c) HF (d) HCl

8. What is the number of the orbitals which can be occupied by electrons in the atoms of the elements located in the sixth period in the periodic table, where the electron has the quantum number ($m_l = +3$) ?

(a) 1 (b) 3 (c) 5 (d) 7

9. One of the students presumed wrongly that the two electrons (X) and (Y) which are in the same atom have the following quantum numbers :

- Electron (X) : $n = 4$, $l = 0$, $m_l = 0$, $m_s = +\frac{1}{2}$
- Electron (Y) : $n = 4$, $l = 0$, $m_l = 0$, $m_s = +\frac{1}{2}$

What is the rule or the principle which explains this mistake ?

(a) Pauli's exclusion principle. (b) Aufbau principle.

(c) Hund's rule. (d) Uncertainty principle.

10. Which of the following equations represents the electron affinity of bromine ?

(a) $Br_{(g)} \longrightarrow Br^+_{(g)} + e^-$ (b) $Br_{(g)} + e^- \longrightarrow Br^-_{(g)}$

(c) $Br_{2(g)} + e^- \longrightarrow 2Br^-_{(g)}$ (d) $Br^+_{(g)} + e^- \longrightarrow Br_{(g)}$

11. Which of the following loses electrons in the redox (oxidation–reduction) reactions ?

(a) The substance which undergoes oxidation.

(b) The cathode.

(c) The oxidizing agent.

(d) The atom or the ion whose oxidation number decreases.

12. Which of the following is a correct application of one of the postulates of Dalton's theory ?

(a) The atoms of a sample of iron are not necessarily similar.

(b) Hydrogen substance is formed of very minute particles called ions.

(c) Water is formed from hydrogen and oxygen elements in a constant weight ratio.

(d) Carbon and hydrogen elements combine in different weight ratios to form many compounds.

13. On the absence of magnetic field or electric field which affects the tube of the cathode rays, the rays ....

(a) are not formed.
(b) move in straight lines.
(c) become positively charged.
(d) do not glow.

14. Which of the following contains the same number of electrons of nitride ion ?

(a) Na^+
(b) N_2
(c) Cl^-
(d) Ar

15. When an electron transfers from higher energy level to a lower energy level, it produces ....

(a) an absorption spectrum.
(b) an emission spectrum.
(c) α - particles.
(d) gamma rays.

16. Which of the following elements has chemical properties similar to those of magnesium element $_{12}Mg$?

(a) Sulphur $_{16}S$
(b) Calcium $_{20}Ca$
(c) Iron $_{26}Fe$
(d) Chlorine $_{17}Cl$

17. Which of the following represents the possible quantum numbers of the last electron in nickel atom $_{28}Ni$?

(a) $n = 3, l = 2, m_l = -1, m_s = -\frac{1}{2}$
(b) $n = 3, l = 2, m_l = 0, m_s = -\frac{1}{2}$
(c) $n = 3, l = 2, m_l = +1, m_s = -\frac{1}{2}$
(d) $n = 3, l = 2, m_l = +1, m_s = +\frac{1}{2}$

18. What is the number of the orbitals of *(f)* sublevel in the principal level (n = 3) ?

(a) Zero
(b) 3
(c) 5
(d) 7

19. Which of the following has the smallest radius ?

(a) F^-
(b) Ne
(c) Na^+
(d) Cl^-

20 What is the name of ClO_4^- ion ?

(a) Chlorite ion.

(b) Hypochlorite ion.

(c) Perchlorite ion.

(d) Perchlorate ion.

21 The oxidation number of manganese is +3 in ....

(a) $KMnO_4$

(b) $Ba(MnO_4)_2$

(c) Mn_2O_3

(d) MnO

22 Which of the following represents the quantum numbers of the farthest electron from the nucleus in scandium atom $_{21}Sc$? Explain.

The first set : $(n = 3 , \ell = 2 , m_\ell = -2 , m_s = +\frac{1}{2})$.

The second set : $(n = 4 , \ell = 0 , m_\ell = 0 , m_s = -\frac{1}{2})$.

....

....

....

....

....

2 marks

23 The following figure represents a section in the periodic table :

(1) What is the difference between the number of representative elements and the number of the main transition elements ?

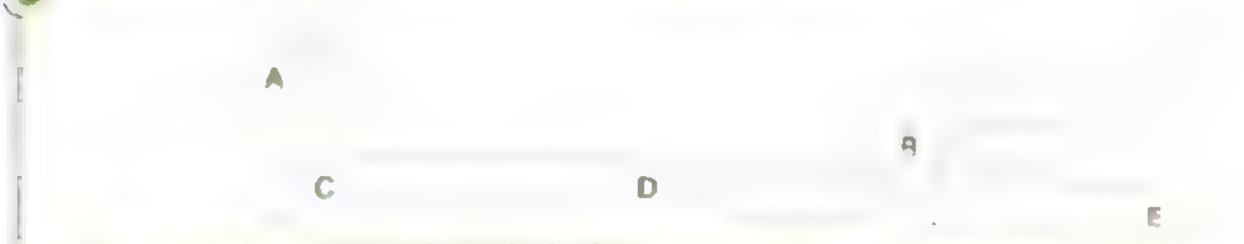
....

....

....

(2) Shade the location of the element which lies in the fourth period, group (3A).

24 The following table represents a section in the periodic table.



What is the hypothetical symbol of the element which is characterized by that:

(1) Its ion carries two positive charges.

(2) Its electron configuration ends with : $4s^2$, $3d^6$

1 mark

25 The compound ClO_2 is formed in industry from the reaction of $NaClO_3$ with HCl

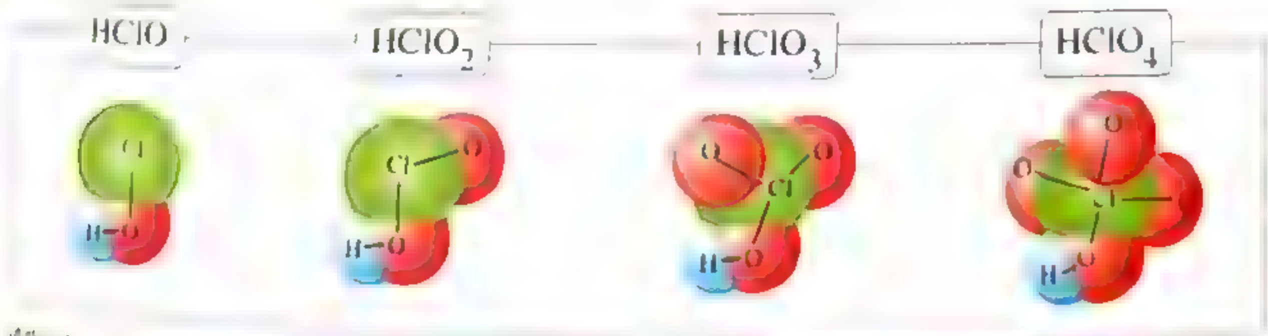
Which of the former three compounds is the compound in which the oxidation number of chlorine is the highest ?

1 mark

26 Write the balanced sym... which represents the reaction of aluminum oxide with sulphuric acid.

1 mark

27 Here are 4 oxygenated acids :



Which of these acids has the lowest (n) value ? What is this (n) value ?

2 marks

Open Book Exam model 3

Answered

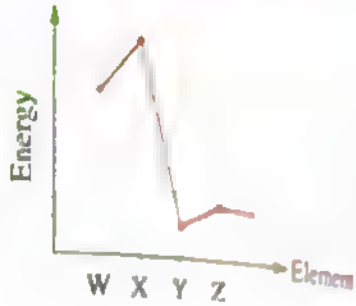
Rate your level

Superior from 20 marks to 21 marks | Remarkable from marks to marks | Above Average from marks to marks | Weak less than 15 marks

Choose the correct answer for the questions (1) : (21) . (21 marks)

1 The opposite figure represents the second ionization potentials of some elements.

Which of them represents $_3Li$?



(a) W

(b) X

(c) Y

(d) Z

2 Element Q is located in the group (6A) in the periodic table, its nucleus contains x number of neutrons and y number of protons.

Which of the following choices represents the ion of this element ?

(a) $^{x+y}_{y}Q^{2+}$ (b) $^{x}_{y}Q^{2+}$ (c) $^{x+y}_{y}Q^{2-}$ (d) $^{x}_{y}Q^{2-}$

3 The oxidation number of carbon equal zero in ....

(a) CH_4 (b) CH_3Br (c) $CHBr_3$ (d) CH_2Br_2

4 Which of the following is an electron configuration of a stable atom ?

(a) [Ne] , $3s^2$, $3p^3$, $4s^1$ (b) $1s^2$, $2s^2$, $2p^4$, $4s^2$

(c) [Ne] , $3s^2$, $3p^6$, $4s^1$ (d) $1s^1$, $2s^1$

5 Which of Dalton's postulates is still valid up till now ?

(a) Atoms are minute particles.

(b) Atom is indivisible.

(c) Atoms of the same element have the same mass.

(d) All the atoms of the same element are different in mass from the atoms of the other elements.

6 Which of these ions its electronic configuration is not similar to that of a noble gas ?

(a) Cl^- (b) Rb^+ (c) Sn^{2+} (d) Mg^{2+}

7. Which of the following are the oxidation numbers of nitrogen and chlorine (respectively) in $NOClO_4$?

(a) +2 and −7 (b) −3 and +5 (c) +2 and +7 (d) +3 and +7

8. Which of the following represents the correct graduation in the properties of the oxides of the elements of the third period ?

Choices	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl_2O_7
(a)	Basic	Basic	Amphoteric	Amphoteric	Amphoteric	Acidic	Acidic
(b)	Basic	Basic	Amphoteric	Acidic	Acidic	Acidic	Acidic
(c)	Basic	Basic	Basic	Amphoteric	Acidic	Acidic	Acidic
(d)	Basic	Basic	Amphoteric	Amphoteric	Acidic	Acidic	Acidic

9. What are the quantum numbers (n), (l) of the orbitals which are occupied successively by electrons in all lanthanides ?

(a) $n = 4 , l = 3$ (b) $n = 3 , l = 4$

(c) $n = 4 , l = 1$ (d) $n = 5 , l = 2$

10. Each of the following matches Pauli's exclusion principle, **except** ....

(a) [↑] [↑↓] [| |]

(b) [↑↑] [↑↓] [| |]

(c) [↑↓] [↑↓] [↑↓ | |]

(d) [↑↓] [↑↓] [↑ | | ↑]

11. Which of the following oxygenated acids is stronger ?

(a) $HClO_2$ (b) HNO_2 (c) HIO_3 (d) HBrO

12. Which of the following choices shows the charge and the location of the electron in the atom ?

Choices	Charge	Present inside the nucleus
(a)	Negative	No
(b)	Negative	Yes
(c)	Positive	No
(d)	Positive	Yes

13 **The line spectrum of sodium contains one coloured line, while the line spectrum of hydrogen contains 4 coloured lines.**

What does this statement indicate ?

(a) Hydrogen molecule is formed of four atoms.

(b) As the power of the spectroscope increases, the number of lines which can be seen increases.

(c) There are four excited electrons in hydrogen atom.

(d) The line spectrum of sodium differs from the line spectrum of the other elements.

14 **According to the modern atomic theory,** ....

(a) the electron can not be found in the same place two successive times.

(b) the electrons need to absorb energy photons continuously to move to higher levels.

(c) the charge of the electron = 1.602×10^{-19} C

(d) it is impossible to determine the position and the velocity of the electron precisely at the same time.

15 **Which of the following sets of quantum numbers is not possible ?**

(a) $n = 2 , \ell = 0 , m_\ell = +1$

(b) $n = 2 , \ell = 1 , m_\ell = +1$

(c) $n = 2 , \ell = 0 , m_\ell = 0$

(d) $n = 2 , \ell = 1 , m_\ell = -1$

16 **Which of the following represents the electronic configuration of manganese (III) ion ?** **(Mn atomic number = 25)**

(a) $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 3d^4$

(b) $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 3d^5 , 4s^2$

(c) $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 3d^2 , 4s^2$

(d) $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 3d^6 , 4s^2$

17 **Which of the following is correct ?**

(a) The elements in the same group have the same number of electrons in the energy levels.

(b) The elements in the periodic table are ordered according to increasing the number of their protons.

(c) The metals are on the right and the nonmetals are on the left of the periodic table.

(d) Active elements are located at the bottom of every group in the periodic table.

18 Which of the following groups its elements electronic configurations end with : ns^2 , np^1 ?

ⓐ 1A
ⓑ 2A
ⓒ 3A
ⓓ 4A

19 Which of the following chemical processes is impossible to occur ?

ⓐ $Ca_{(g)} + Energy \longrightarrow Ca^{2+}_{(g)} + 2e^-$
ⓑ $K_{(g)} + e^- \longrightarrow K^+_{(g)} + Energy$
ⓒ $H_{2(g)} + Energy \longrightarrow 2H^+_{(g)} + 2e^-$
ⓓ $Cl_{(g)} + e^- \longrightarrow Cl^-_{(g)} + Energy$

20 Four different elements : ${}_{12}A$, ${}_{4}B$, ${}_{38}C$, ${}_{56}D$

Why do these elements belong to the same group in the modern periodic table ?

ⓐ Because they are all metals which can combine with oxygen forming oxides with a general formula MO
ⓑ Because they are all non[illegible] can form ions with the symbol M^{2-}
ⓒ Because they are all non[illegible] valence shells contain 2 electrons.
ⓓ Because they are all metal[illegible] electron configurations end with ns^2

21 Chlorine replaces iodide ion in [illegible] iodide solution according to the equation : $Cl_2 + 2I^- \longrightarrow I_2 + 2Cl^-$

What is the oxidizing agent in this reaction ?

ⓐ Chloride ions.
ⓑ Chlorine gas.
ⓒ Iodide ions.
ⓓ Iodine vapours.

22 The electron configuration of the element (X) ends with the sublevel $4s^1$

What is the product of ionization of XOH in water ? Explain.

....

....

2 marks

23 The atoms of the elements in the periodic table -except hydrogen- contain protons, neutrons and electrons :
What is the effect of passing an electron current between the two electrodes of an electric field as shown in the opposite figure ? **Explain.**

....

....

1 mark

24 **Can two elements** in the fourth period in the periodic table be similar in containing *3d* sublevel in each of them half filled with 5 unpaired electrons ?
Explain your answer.

....

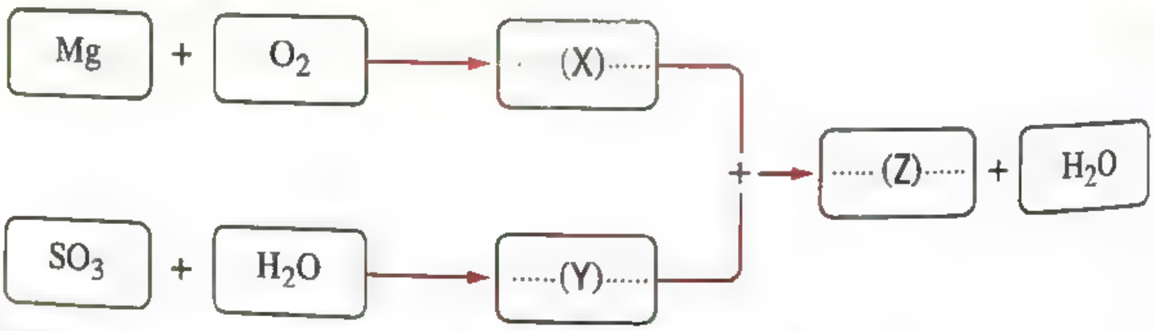
....

....

....

1 mark

25 **Study the scheme, then answer :**



(1) **Write** the chemical formula of the two compounds (X) and (Y).
(X) : ....
(Y) : ....

(2) **Write** the symbolic equation which represents the reaction of (X) with (Y) to form the salt (Z).

....

....

....

2 marks

26 The opposite table shows the four quantum numbers of the last electron in the atom of each of the element (X) and the element (Y).

Quantum numbers	(n)	(ℓ)	(m_ℓ)	(m_s)
Element (X)	2	1	0	$+\frac{1}{2}$
Element (Y)	6	1	0	$+\frac{1}{2}$

Which of the two elements when its pure vapours are exposed to low pressure in a discharge tube, its last electron becomes excited, and acquires the same quantum numbers of the other element ? Explain.

....

....

....

....

....

1 mark

27 The opposite table illustrates the radii of some atoms and ions.

H	Cl	Na	Na^+	Cl^-
0.3 Å	0.99 Å	1.57 Å	0.95 Å	1.81 Å

Calculate the bond length in each of :

(1) Hydrogen chloride molecule.

....

(2) Sodium chloride formula unit.

....

2 marks

Choose the correct answer for the questions 1 : 21

21 marks

1. The term electron was not known at the time of formulating ....
   - (a) Rutherford's atomic model.
   - (b) Bohr's atomic model.
   - (c) Thomson's atomic model.
   - (d) Bohr's modified atomic model.

2. If the principal quantum number of the last electron in the atom of a noble gas is (n = 3).
   What is the number of the orbitals which are completely filled with electrons in this atom ?
   - (a) 3
   - (b) 5
   - (c) 7
   - (d) 9

3. What is the number of the unpaired (single) electrons in the atom of phosphorus $_{15}P$?
   - (a) 1
   - (b) 2
   - (c) 3
   - (d) 4

4. Bromine is similar to chlorine in all the f... ...cept that ....
   - (a) they are located in the same block in ... ...able.
   - (b) they have the same oxidation number...
   - (c) they are located in the same group.
   - (d) they are located in the same period.

5. What is (are) the type(s) of the two elements whose ions form iron (II) sulphide ?
   - (a) Main transition metal and representative nonmetal.
   - (b) Representative metal and representative nonmetal.
   - (c) Inner transition metal and metalloid.
   - (d) Both are representative metals.

6. What is the correct descending order of the electron affinities of carbon, oxygen, fluorine and chlorine ?
   - (a) Cl > F > O > C
   - (b) O > C > F > Cl
   - (c) F > C > O > Cl
   - (d) C > O > Cl > F

7. Which of the following pairs of atomic numbers belongs to two elements which are located in the same block and the same period in the modern periodic table ?
   - (a) 41 , 74
   - (b) 8 , 36
   - (c) 64 , 68
   - (d) 12 , 72

8 Which of the following electronic configurations belongs to an atom of an element which the difference between its third and second ionization potentials is very high ?

(a) $1s^2, 2s^2, 2p^6, 3s^1$
(b) $1s^2, 2s^2, 2p^6, 3s^2, 3p^1$
(c) $1s^2, 2s^2, 2p^6, 3s^2, 3p^2$
(d) $1s^2, 2s^2, 2p^6, 3s^2$

9 When MnO_4^- is converted to Mn^{2+}, this is described as

(a) a reduction process, because the oxidation number of Mn increases
(b) an oxidation process, because the oxidation number of Mn increases
(c) a reduction process, because the oxidation number of Mn decreases
(d) an oxidation process, because the oxidation number of Mn decreases

10 Which of the following oxides is the most basic oxide ?

(a) Al_2O_3
(b) K_2O
(c) CO_2
(d) MgO

11 When (n = 6), then the correct sequence of filling the sublevels with electrons is

(a) $ns \longrightarrow (n-2)f \longrightarrow (n-1)d \longrightarrow np$
(b) $ns \longrightarrow (n-1)d \longrightarrow (n-2)f \longrightarrow np$
(c) $ns \longrightarrow (n-2)f \longrightarrow np \longrightarrow (n-1)d$
(d) $ns \longrightarrow np \longrightarrow (n-1)d \longrightarrow (n-2)f$

12 Which of the following can not be explained by Dalton's model of the atom ?

(a) The law of constant p[illegible]
(b) The difference betw[illegible]nent and the compound.
(c) The difference betwe[illegible]opes of the same element.
(d) The difference in the a[illegible]sses of the elements.

13 When the last electron in sodium atom is excited to the energy level (n = 5), it ....

(a) remains in the energy level (n = 5).
(b) returns to the energy level (n = 3) in one jump.
(c) returns to the energy level (n = 4) then to (n = 2).
(d) returns to the energy level (n = 2).

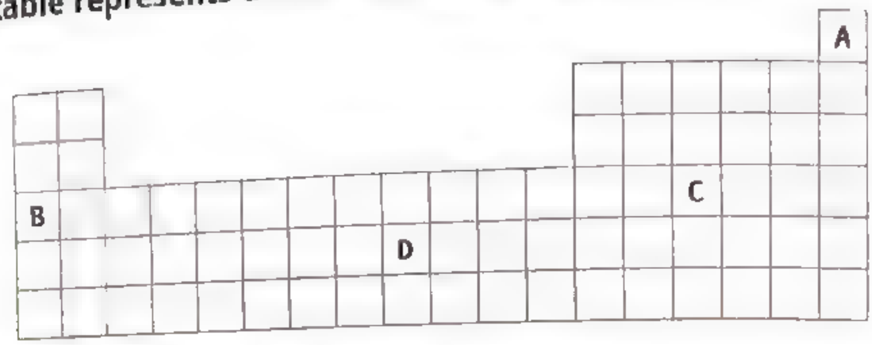
14 Each of the following sets of quantum numbers is possible, except ....

Choices	(n)	(l)	(m_l)	(m_s)
(a)	3	1	−1	0
(b)	3	2	+2	$-\frac{1}{2}$
(c)	4	3	+2	$-\frac{1}{2}$
(d)	5	3	+2	$+\frac{1}{2}$

15. What is the correct electron configuration of magnesium ion Mg^{2+} in the excited state ?

ⓐ $1s^2, 2s^2, 2p^5, 3s^2$
ⓑ $1s^2, 2s^2, 2p^6, 3s^1$
ⓒ $1s^2, 2s^2, 2p^6$
ⓓ $1s^2, 2s^2, 2p^5, 3s^1$

16. The following table represents a section in the periodic table :



Which of the following describes one of these elements ?

ⓐ Element A ends with the electronic configuration : ns^2, np^6
ⓑ Element B has more than one oxidation number.
ⓒ Element C is a metalloid.
ⓓ Element D is an inner transition element.

17. Each of the following describes the element $_{17}M$, except that ....

ⓐ it is an electronegative nonmetal.
ⓑ it forms M^+ which contains 4 unpaired electrons.
ⓒ its oxidation numbers range between –1 to +7
ⓓ it forms acidic oxides such as : M_2O_3 and M_2O_5

18. What is the atomic number of the element which is located in the sixth period in the periodic table and it is an alkali earth metal ?

ⓐ 56
ⓑ 55
ⓒ 87
ⓓ 88

19. The opposite table shows the types of the oxides of four elements which belong to the same group.
What is the letter which refers to the element with the lowest electronegativity ?

Element	Type of its oxide
P	Acidic
Q	Amphoteric
R	Amphoteric
S	Basic

ⓐ R
ⓑ Q
ⓒ P
ⓓ S

... are : HBrO , $HBrO_2$, $HBrO_3$

Which of the following expresses one of these acids ?

(a) HBrO is the weakest acid among these three acids.

(b) Oxidation number of bromine in $HBrO_3$ equals (–1).

(c) $HBrO_2$ is the strongest acid among these three acids.

(d) The ratio (n : m) in HBrO equals (1 : 1).

21 In the reaction : $Sb_2O_3 + 6H^+ + 6e^- \longrightarrow 2Sb + 3H_2O$

What is the change in the oxidation number of Sb ?

(a) It increases by 3

(b) It decreases by 3

(c) It increases by 6

(d) It decreases by 6

22 The opposite table shows the ionization potentials (first to fifth) of one of the elements of the third period in the modern periodic table.

Ionization potential (kJ/mol)				
First	Second	Third	Fourth	Fifth
+577.9	+1820	+2750	+11600	+14800

Deduce the electron configuration of this element and calculate its atomic number.

....

....

...... 1 mark

23 The last electron in the atom of an element has the quantum numbers :

$$(n = 3 , \ell = 1 , m_\ell = -1 , m_s = -\frac{1}{2})$$

Determine the location of this element in the periodic table.

....

....

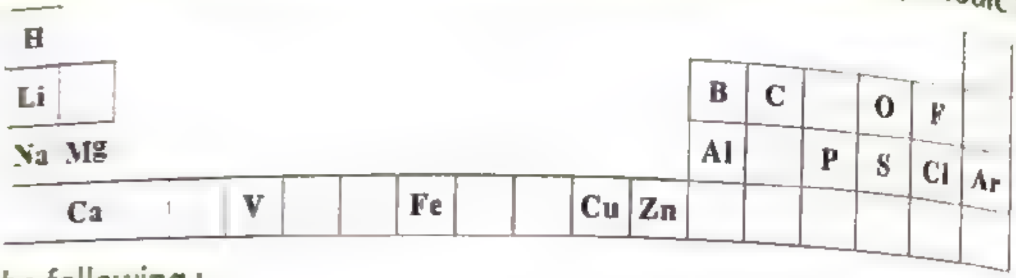
...... 1 mark

24 Illustrate the electronic configuration to the nearest noble gas of a representative element which is located in the 4^{th} period, group 5A

....

...... 1 mark

25 The following figure represents the first four periods in the modern periodic table.



Answer the following :

(1) **What** is the number of the unpaired electrons in the ion of Mg ?

....

(2) **Circle the two elements** which combine together to form a compound that glows when an α-particle collide with it.

State the name of this compound.

....

...... 2 marks

26 If you know that the bond length in ammonia molecule NH_3 equals 1 Å, and in hydrogen molecule H_2 equals 0.6 Å, while in water molecule H_2O equals 0.96 Å

Calculate the bond length in NO molecule.

....

....

....

....

....

....

....

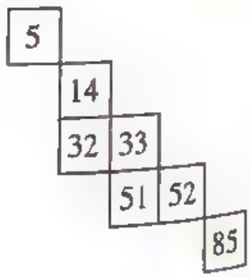
....

....

....

...... 2 marks

27 The opposite figure shows a section in the periodic table :



(1) **What** do these numbers refer to ?

....

(2) **What** is the common feature in these elements ?

....

....

...... 2 marks

... marks : 27 marks	from 26 to 21 marks	from 20 to 15 marks	less than 15 marks	Weak

Choose the correct answer for the questions (1) : (21) .

21 marks

1 Number of electrons present in the orbitals of each of s and p sublevels is the same in the atom of ....

(a) $_{7}N$ (b) $_{11}Na$
(c) $_{12}Mg$ (d) $_{14}Si$

2 The following are some postulates of the theories which explain the atomic structure :

- Theory (A) : The electronic shells surround the nucleus which is in the center of the atom.
- Theory (B) : The atom is invisible solid sphere.
- Theory (C) : The atom contains vast space.

What is the historical order of these three theories ?

(a) $A \longrightarrow B \longrightarrow C$ (b) $B \longrightarrow C \longrightarrow A$
(c) $A \longrightarrow C \longrightarrow B$ (d) $B \longrightarrow A \longrightarrow C$

3 The ratio between the size of the cation to that of the anion is maximum in ....

(a) CsI (b) CsF
(c) LiF (d) NaF

4 All the following combinations of the quantum numbers are not allowed, except ....

(a) $n = 2 , l = 2 , m_l = +1$ (b) $n = 2 , l = -1 , m_l = 0$
(c) $n = 3 , l = 2 , m_l = +3$ (d) $n = 4 , l = 3 , m_l = -2$

5 Which of the following electron configurations does not verify both Hund's rule and the exclusion principle together ?

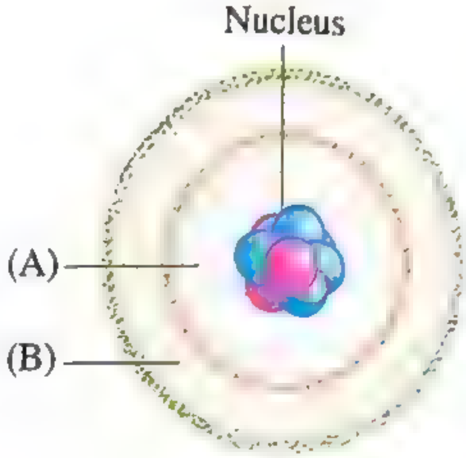
(a) [⇅] [↑↑ | ↑ |] (b) [⇅] [⇅ | | ⇅]
(c) [⇅] [↓ | ↓ | ↓] (d) [⇅] [⇅ | ⇅ | ↑]

6. In the opposite table.
What does (X) represent ?

Element	Li	Be	B	C	N	O	F
Atomic number	3	4	5	6	7	8	9
(X) values	1.28	1.91	2.42	3.14	3.83	4.45	5.10

ⓐ Ionization potential.
ⓑ Electronegativity.
ⓒ Effective nuclear charge.
ⓓ Electron affinity.

7. The opposite figure represents an atom of an element.
Which of the following represents (A) and (B) ?



Choices	(A)	(B)
ⓐ	Orbital	Orbital
ⓑ	Electron cloud	Electron cloud
ⓒ	Electron cloud	Orbital
ⓓ	Orbital	Electron cloud

8. What is the correct order which represents the numbers of the single (unpaired) electrons in the ions of these transition elements ?

ⓐ $Cu^{2+} > Ni^{2+} > Cr^{3+} > Fe^{3+}$
ⓑ $Cr^{3+} > Fe^{2+} > Ni^{2+} > Cu^{2+}$
ⓒ $Fe^{3+} > Cr^{3+} > Cu^{2+} > Ni^{2+}$
ⓓ $Fe^{3+} > Cr^{3+} > Ni^{2+} > Cu^{2+}$

9. Three acids which are : $HClO$, $HBrO_4$, HIO_3
Which choice represents a similarity and a difference between these acids ?

Choices	The similarity	The difference
ⓐ	Oxidation number of the central atom	Oxidation number of O atom
ⓑ	Their strengths as oxygenated acids	Their hydroxy formula
ⓒ	Oxidation number of the central atom	Number of oxygen atoms nonbinded to hydrogen
ⓓ	Oxygenated halogen acids	Their strengths as oxygenated acids

10 Which of the following represents the number of the natural noble gases in the periodic table ?

Choices	In the same period	In group zero	In p-block	In the periodic table
(a)	1	6	0	6
(b)	1	6	6	6
[illegible]	0	5	6	5
[illegible]	6	6	0	5

11 What are the two elements which have almost the same ionization potential ?

(a) $_{13}Al$, $_{31}Ga$ (b) $_{38}Sr$, $_{31}Ga$

(c) $_{31}Ga$, $_{87}Fr$ (d) $_{87}Fr$, $_{13}Al$

12 The periodic table includes the known elements arranged according to their ....(1).... , in the group (1A) the metallic property ....(2).... from the top to the bottom, and in the group ([illegible]) the electronegativity ....(3).... from the bottom to the top.

Which of the following choi[illegible] the numbers (1), (2) and (3) in the previous statement ?

Choices	(1)	(2)	(3)
[illegible]	atomic numbers	increases	decreases
[illegible]	atomic numbers	increases	increases
[illegible]	mass numbers	decreases	increases
[illegible]	mass numbers	increases	decreases

13 Chlorine has an oxidation number +5 in ....

(a) $NaClO$ (b) $NaClO_2$

(c) $NaClO_3$ (d) $NaClO_4$

14 How many unpaired electrons does a ground state $_{24}Cr^{2+}$ ion have ?

(a) 0   (b) 2

(c) 4   (d) 6

15 **Which of the following expresses an element in the periodic table ?**

(a) The element whose atomic number is 48 is located in group (IIB), fifth period.

(b) The element whose electronic configuration is [Xe], $4f^{14}$, $5d^{3}$, $6s^{2}$ is located in group (IIIB), sixth period.

(c) The element whose electronic configuration is [Rn], $6d^{2}$, $7s^{2}$ is located in group (VB), seventh period.

(d) The element whose atomic number is 56 is located in group (IIIA), sixth period.

16 **An ion which contains 18 electrons and its charge is +2 , ...**

(a) its nucleus contains 18 protons.

(b) has the symbol Ar^{2+}

(c) has 18 neutrons.

(d) has the same electronic configuration of argon.

17 **The fourth period in the modern periodic table contains ....**

(a) 10 metals.

(b) 32 elements.

(c) one of the metalloids.

(d) number of transition elements [illegible] number of the elements of s and p-blocks.

18 **The opposite table shows the quantum numbers of the last electron which has the highest energy in the atom of an element.**

[illegible] numbers	(n)	(ℓ)	(m_ℓ)	(m_s)
Last electron	3	2	+2	$-\frac{1}{2}$

What is the type of the oxide of this element ?

(a) Acidic. (b) Basic. (c) Neutral. (d) Amphoteric.

19 **All the following statements are correct, <u>except</u> ....**

(a) the wave mechanical theory of the atom is currently the accepted atomic model.

(b) the electron moves away from the nucleus upon being excited.

(c) according to Dalton's atomic model, the elements can combine chemically to form the compounds.

(d) Rutherford's experiment is the first to discover the presence of the negatively charged electrons in the atom.

20 The element whose electron configuration : [Xe], $4f^{13}$, $6s^2$ belongs to .

ⓐ the third main transition series.
ⓑ lanthanides.
ⓒ the second main transition series.
ⓓ actinides.

21 Which of the following quantum numbers represent one of the electrons of the partially occupied orbitals in the atom of vanadium $_{23}V$?

Choices	n	ℓ	m_ℓ	m_s
ⓐ	3	1	0	$-\frac{1}{2}$
ⓑ	3	2	0	$+\frac{1}{2}$
ⓒ	4	1	0	$+\frac{1}{2}$
ⓓ	5	2	+1	$-\frac{1}{2}$

22 The opposite table represents the values of the electron affinities of the halogens.
Fill in the spaces with two suitable values of the following three values :

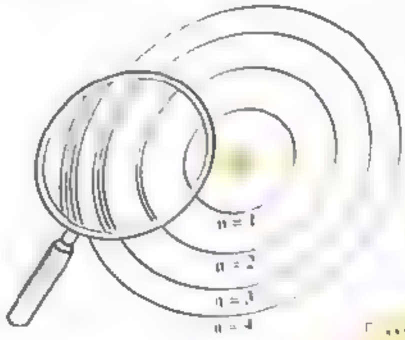
-324.5 , -400 , -295

Element	Electron affinity
Fluorine	– 328 kJ/mol
Chlorine	– 348.6 kJ/mol
Bromine	.... kJ/mol
Iodine	.... kJ/mol

1 mark

23 Deduce the relation which is illustrated by the opposite diagram.

....
....
....



1 mark

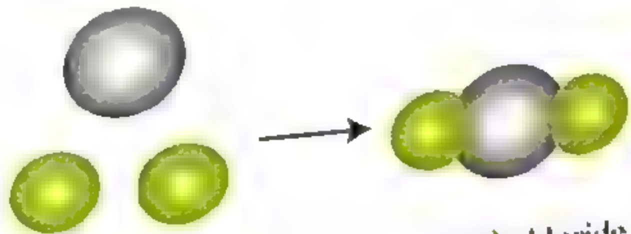
24 The opposite figure represents one of the postulates of a theory you have studied :

(1) What is this theory ?

....

(2) State the postulate illustrated in the figure.

....



2 marks

25 Rubidium Rb is one of the alkali metals.

Write the symbolic balanced equation which represents the reaction of rubidium oxide with water.

....

1 mark

26 An element contains one electron in the last sublevel,

if the quantum numbers of that electron are : ($n = 3$, $l = 1$, $m_l = -1$, $m_s = +\frac{1}{2}$)

(1) **Calculate** the atomic number of the element.

....

....

(2) **Mention** the number of the group in which the element is located.

....

2 marks

27 If you know that :

- (O – H) bond length in water molecule equals [illegible] Å
- Bond length in oxygen molecule equals 1 [illegible]

Calculate the bond length in hydrog[illegible]

....

....

....

....

....

....

2 marks

Open Book Exam model 6

Answered

Rate your level

Superior: from 30 marks to 27 marks | Remarkable: from 26 marks to 21 marks | from marks to marks | Weak: less than 15 marks

• Choose the correct answer for the questions (1) : (21) .

21 marks

(1) What is the block of the element whose electronic configuration is
[Kr] , $4d^{10}, 4f^{4}, 5s^{2}, 5p^{6}, 6s^{2}$?

(a) s-block. (b) p-block. (c) d-block. (d) f-block.

(2) The opposite table shows the first three ionization potentials E_1 , E_2 and E_3 of an element.
What is the most stable oxidation state of this element ?

E_1	E_2	E_3
7 eV	12.5 eV	42.5 eV

(a) +1 (b) +2 (c) +3 (d) +4

(3) Which of the following valence electrons are affected by the highest effective nuclear charge ?

(a) $4s^1$ (b) $4p^1$ (c) $3d^1$ (d) $2p^3$

(4) Four elements P , Q , R and S are located in p-block in the third period in the periodic table, they are ordered according to electronegativity as follows : S > R > Q > P
Which of the following compounds liberates H^+ ion easier ?

(a) P – O – H (b) S – O – H (c) Q – O – H (d) R – O – H

(5) Iron (II) chloride reacts with chlorine as follows :

$$2FeCl_2 + Cl_2 \longrightarrow 2FeCl_3$$

Which of the following statements is correct ?

(a) Fe^{2+} ions are reduced to Fe^{3+} ions and chlorine acts as oxidizing agent.
(b) Fe^{2+} ions lose electrons and chlorine acts as reducing agent.
(c) Fe^{2+} ions lose electrons and Cl_2 molecules are reduced to Cl^- ions.
(d) Cl_2 molecules are reduced to Cl^- ions and chlorine acts as reducing agent.

(6) What is the symbol of the element which is located in group (3A), fifth period in the periodic table ?

(a) $_{13}Al$ (b) Ti (c) Nb (d) $_{49}In$

7 An electron with the quantum numbers :

$$(n = 4 , \ell = 1 , m_\ell = -1 , m_s = +\tfrac{1}{2}).$$

What is the sublevel of this electron ?

ⓐ *4s* ⓑ *4p* ⓒ *4d* ⓓ *4f*

8 What are the two elements which are located in the same period in the periodic table ?

ⓐ Mg , Sb ⓑ Ca , Zn

ⓒ Na , Ca ⓓ Ca , Cl

9 What is the proper graduation in electronegativity in these four shown elements ?

ⓐ C < N < Si < P ⓑ Si < P < C < N

ⓒ N < C < P < Si ⓓ C < Si < N < P

10 The opposite table shows the first and second ionization potentials of four elements : P , Q , R and S. What is the most active metal in this group of elements ?

Element	First ionization potential	Second ionization potential
S	2372 kJ/mol	5251 kJ/mol
R	520 kJ/mol	7300 kJ/mol
Q	[illegible]	1760 kJ/mol
P	[illegible]	3380 kJ/mol

ⓐ S ⓑ P

ⓒ R ⓓ Q

11 What is the number of elements in the fourth [illegible] periodic table, in which the orbitals of *3d* sublevel are occupied by one electron or more ?

ⓐ 16 ⓑ 10 ⓒ 9 ⓓ 0

12 Which of the following electronic transitions in hydrogen atom is accompanied by maximum release of energy ?

ⓐ $(n = 2) \longrightarrow (n = 1)$. ⓑ $(n = 3) \longrightarrow (n = 2)$.

ⓒ $(n = 4) \longrightarrow (n = 3)$. ⓓ $(n = 2) \longrightarrow (n = 4)$.

13 The maximum value of (m_ℓ) for an electron in the fourth energy level is ....

ⓐ +3 ⓑ +4 ⓒ +5 ⓓ +9

14 Nitrogen has atomic number 7 and oxygen has atomic number 8

What is total number of electrons in $(NO_3)^-$ ion ?

ⓐ $15e^-$ ⓑ $31e^-$

ⓒ $32e^-$ ⓓ $46e^-$

15 The electron configuration $1s^2$, $2s^2$, $2p^5$, $3s^1$ shows ..

ⓐ the ground state of fluorine.

ⓑ an excited state of fluorine.

ⓒ an excited state of neon.

ⓓ the ground state of O^{2-} ion.

16 Bohr's model could explain successfully the spectrum of ....

ⓐ the multi-electron atoms.

ⓑ helium.

ⓒ any atom or ion containing only one electron.

ⓓ hydrogen molecule.

17 According to Hund's rule and Pauli's exclusion principle, the two last electrons which have the highest energy in the atom of $_{26}Fe$ element are different in the two quantum numbers ....

ⓐ l , m_l

ⓑ n , m_l

ⓒ l , m_s

ⓓ m_l , m_s

18 The opposite figure represents a s[illegible] the periodic table. In which of the illustrated areas a diatomic molecule element which does not conduct electricity is found ?

ⓐ A

ⓑ B

ⓒ C

ⓓ D

19 Cathode rays are deflected away from the negatively charged metal plate, because they are ....

ⓐ non-material particles.

ⓑ negatively charged.

ⓒ emitted from all materials.

ⓓ positively charged.

20 Which of the following is the electron configuration of iron cation in $Fe(OH)_2$?

(knowing that the atomic number of iron = 26)

ⓐ [Ar] , $4s^2$, $3d^6$

ⓑ [Ar] , $4s^2$, $3d^4$

ⓒ [Ar] , $4s^0$, $3d^6$

ⓓ [Ar] , $4s^2$, $3d^8$

21 Which transformation is an oxidation ?

◯ $VO_3^- \longrightarrow VO_2^-$ ◯ $CrO_2^- \longrightarrow CrO_4^{2-}$

◯ $SO_3 \longrightarrow SO_4^{2-}$ ◯ $NO_3^- \longrightarrow NO_2^-$

22 The opposite table shows the values of the quantum numbers of the last electron in the atom of the element (X).

Quantum numbers	(n)	(ℓ)	(m_ℓ)	(m_s)
Element (X)	4	1	0	$+\frac{1}{2}$

Deduce the four quantum numbers of the last electron in the atom of element (Y) which follows element (X) in the same group in the periodic table.

1 mark

23 Write the four quantum numbers of the electron number 11 in each of sodium and magnesium atoms

1 mark

24 Figure (1) shows the falling app ... around the trunk of their tree in circles with different rad

Figure (1)

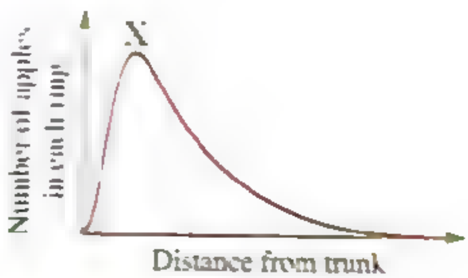


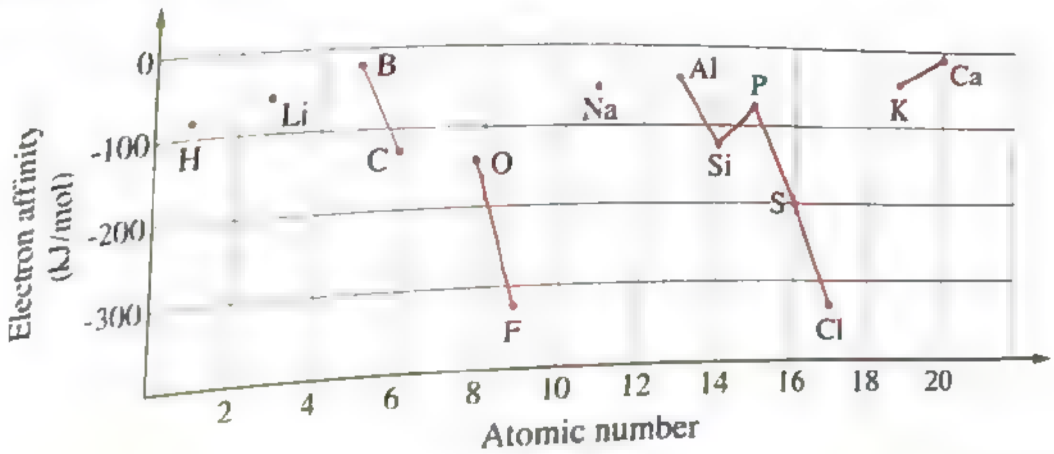
Figure (2)

In the light of understanding the different atomic theories.
What does the symbol (X) in the figure (2) represent ?

....

1 mark

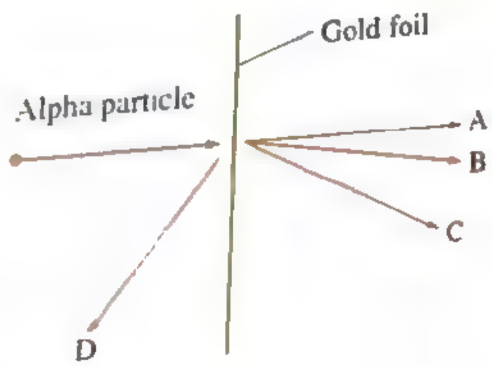
25 The following graph represents the values of the electron affinity of the first twenty elements in the periodic table :



Why were the symbols [He , Be , N , Ne , Mg , Ar] neglected to be mentioned in this graph ?

2 marks

26 The opposite figure shows ... ths of alpha particles, when a bea... a foil of gold :



(1) Which of the shown letters represents the path of one in every 20000 alpha particles ?

(2) What can be deduced from this observation ?

2 marks

27 Here are five different oxides of different elements :

Na_2O , MgO , Al_2O_3 , SO_2 , Cl_2O

Which of these oxides :

(1) Includes the element bound to oxygen which has the highest oxidation number ?

Calculate this oxidation number.

....

....

(2) Dissolves in water forming a monoprotic acid,

write the balanced symbolic equation which represents this.

....

....

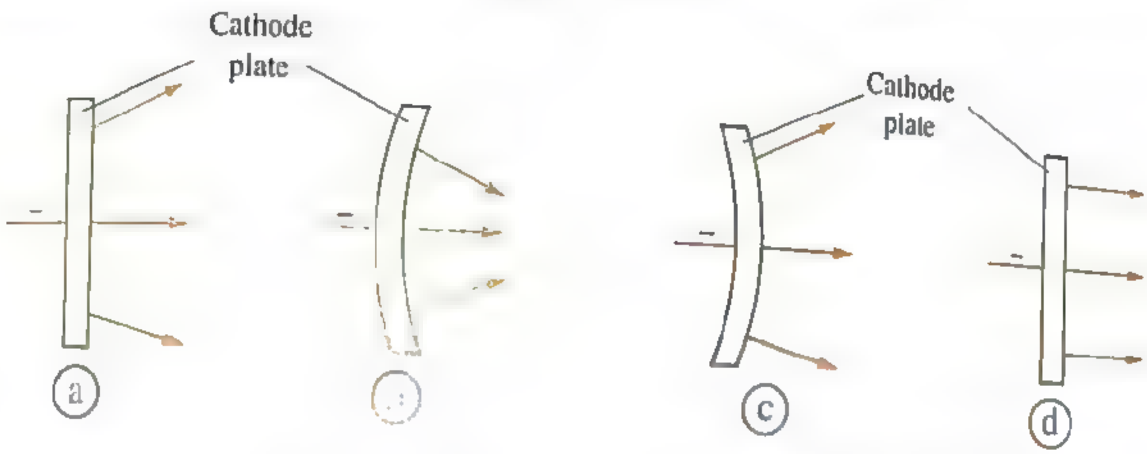
...... 2 marks

• Choose the correct answer for the questions 1 : 21 .

1. Which of the following electronic configurations represents the element that is the most electropositive ?

ⓐ [He], $2s^1$
ⓑ [Ne], $3s^2$
ⓒ [Xe], $6s^1$
ⓓ [Xe], $6s^2$

2. Each of the following figures shows the path of the cathode rays emitted from the surface of the cathode plate, except ....



3. The element with the least atomic number that has the stable electronic configuration : $(n-1)d^6$, ns^2 is located in the ....

ⓐ sixth period.
ⓑ fifth period.
ⓒ fourth period.
ⓓ third period.

4. If the radius of the first orbital in H atom equals x Å, so the radius of the second orbital in Li^{2+} ion is ....

ⓐ x Å
ⓑ $\frac{4}{3}x$ Å
ⓒ $\frac{9}{2}x$ Å
ⓓ $4x$ Å

5. Which of the following transfers of the electron of hydrogen atom is accompanied by releasing the largest amount of energy ?

ⓐ $n = 4 \longrightarrow n = 2$
ⓑ $n = 5 \longrightarrow n = 2$
ⓒ $n = 2 \longrightarrow n = 1$
ⓓ $n = 7 \longrightarrow n = 2$

6 **Why are there no values for the electronegativities of the elements whose atomic numbers are 2 , 10 and 18 ?**

(a) Because they are gaseous substances.

(b) Because they are amphoteric.

(c) Because they are radioactive.

(d) Because their electronic configurations are stable.

7 **What is the number of orbitals in the level (n = 3) ?**

(a) 3 (b) 5

(c) 7 (d) 9

8 **What is the similarity between the metal atom M and its ion M^{3+} ?**

(a) The radius. (b) Number of electrons.

(c) Nuclear charge. (d) Ionization potential.

9 **The following electronic configurations represent four different elements. Which of them has the highest ionization potential ?**

(a) [Ne], $3s^2$, $3p^1$ (b) [Ne] $3s^2$ $3p^1$

(c) [Ne], $3s^2$, $3p^4$ (d) [Ar], $3d^{10}$, $4s^2$, $4p^3$

10 **Which of the following equations represents an oxidation-reduction reaction ?**

(a) $CaCl_2 + Na_2SO_4 \longrightarrow CaSO_4 + 2NaCl$

(b) $KOH + HNO_3 \longrightarrow KNO_3 + H_2O$

(c) $N_2 + O_2 \longrightarrow 2NO$

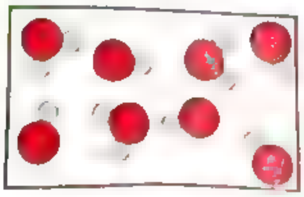
(d) $AgNO_3 + NaCl \longrightarrow NaNO_3 + AgCl$

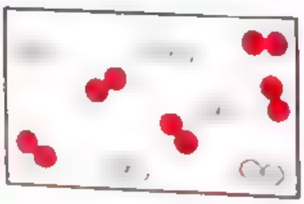
11 **Which of the following choices is incompatible with the building-up principle ?**

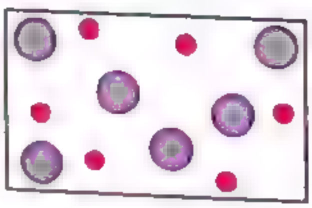
(a) [↑↓] [↑↑ | ↑ | ↑] (b) [↑↓] [↑ | ↑ | ↑]

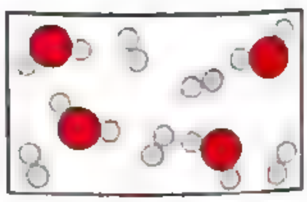
(c) [↑] [↑↓ | ↑ | ↑] (d) [↑↓] [↑↓ | ↑↓ | ↑]

12 **Which of the following represents a mixture of two of group zero elements ?**


(a)


(b)


(c)


(d)

13 Which of the following electron configurations includes two unpaired (single) electrons ?

(a) $1s^2, 2s^2$
(b) $1s^2, 2s^2, 2p^3$
(c) $1s^2, 2s^2, 2p^4$
(d) $1s^2, 2s^2, 2p^5$

14 Which of the following processes represents the formation of a strong acid as a result of an oxidation process ?

(a) $H_2SO_3 \longrightarrow H_2S$
(b) $HClO_4 \longrightarrow HCl$
(c) $H_2SO_3 \longrightarrow H_2SO_4$
(d) $HCO_3^- \longrightarrow H_2CO_3$

15 Which of the following elements atoms releases the highest amount of energy when it gains an electron in its gaseous state ?

(a) C
(b) O
(c) Si
(d) S

16 The isotopes of the same element are similar in the atomic number and different in the mass number, this fact contradicts the postulates of the atomic theory of ....…

(a) Bohr.
(b) Rutherford.
(c) Dalton.
(d) Thomson.

17 Which of the following cases represents the transfer of an excited electron back to its ground energy level ?

(a) $1s^2, 2s^2, 2p^5 \longrightarrow 1s^2$, [illegible] $3s^1$
(b) $1s^2, 2s^2, 2p^6, 4s^1 \longrightarrow 1s$ [illegible] $3s^1$
(c) $[Ar], 4s^2 \longrightarrow [Ne], 3s^2$
(d) $2, 8, 7 \longrightarrow [Ne], 3s^2, 3p^5$

18 The history of proving the presence of a nucleus inside the atom of the element goes back to after ....

(a) Bohr.
(b) Thomson.
(c) Rutherford.
(d) Heisenberg.

19 Which of the following supports the dual nature of the electrons ?

(a) The emission spectrum of hydrogen atom.
(b) The deflection of some α-particles on collision with gold foil.
(c) The penetration of some α-particles on collision with gold foil.
(d) The properties of the cathode rays.

20 Which of the following choices represents an impossible combination of quantum numbers ?

Choices	(n)	(l)	(m_l)	(m_s)
(a)	3	2	+2	$-\frac{1}{2}$
(b)	3	1	−1	$+\frac{1}{2}$
(c)	4	3	+2	$+\frac{1}{2}$
(d)	5	2	+3	$-\frac{1}{2}$

21 Each of the following matches Pauli's principle, except ....

(a) [↑↓] [↑↓][ ][ ]

(b) [↑↑] [↑][↑][↑]

(c) [↑↓] [↑][↓][↑]

(d) [↑] [↑][↑][↑]

22 What is the difference between the oxid[illegible] of potassium in potassium permanganate compound and in potassium dichromate compound ? Ex[illegible]

....

....

....

1 mark

23 What is the maximum number of electrons can be found in an atom and have the following quantum numbers :

$$(n = 1\ ,\ l = 0\ ,\ m_l = 0)$$

....

1 mark

24 Do the values in the following table agree with the graduation of the property of ionization potential in the periodic table ? Explain.

The element	First ionization potential
Phosphorus $_{15}P$	+1012 kJ/mol
Sulphur $_{16}S$	+1000 kJ/mol

2 marks

25 The following figure represents a secti[illegible] periodic table.

Write the letter that indicates the element which conducts the electricity better than silicon, and mention its block in the periodic table.

1 mark

26 The following diagram illustrates the reaction of an alkali with an acidic oxide to form a salt that dissolves in water :

2 KOH	+	......(1)	$\longrightarrow$	......(2)	+	......(3) ......
Alkali		Acidic oxide		Water		Salt

(1) **Complete** the previous diagram with chemical formulas that fulfill a correct balanced symbolic chemical equation.

(1) : .... **(2) :** ....

(3) : ....

(2) **Deduce** the values of (n) and (m) of the oxygenated acid which is produced from dissolving the acidic oxide – in the chemical equation – in water.

....

....

....

....

....

.... 2 marks

27 The following table illustrates the values [illegible] radii of the molecules of some elements :

The molecule	H – H	......(1)......	......(2)......	......(3)......	......(4)......
The covalent atomic radius	0.3 Å	0.99 Å	1.33 Å	1.14 Å	0.64 Å

(1) **Complete** the blanks in the table with the suitable molecules of the first four elements in the halogens group.

(1) : .... **(2) :** ....

(3) : .... **(4) :** ....

(2) **Calculate** the bond length in hydrogen chloride molecule.

....

....

....

....

....

.... 2 marks

• Choose the correct answer for the questions 1 : 21 .

21 marks

1 The visible spectrum of hydrogen atom shows ....

(a) the presence of sublevels in each principal level.
(b) the presence of definite energy levels.
(c) the possibility of the emission of a quantum from the orbital of $1s$
(d) the presence of different isotopes of hydrogen atom.

2 The electronic configuration of the element (X) ends with the sublevels :
$(n-1)s^2$, $(n-1)p^6$, $(n-1)d^5$, ns^2
If (n = 4) , then the atomic number of (X) = ...

(a) 15
(b) 25
(c) 30
(d) 35

3 The element (X) is located in the third period, group (5A) and the element (Y) is in the fifth period, group (15).
What is the atomic number of the element which is located in between them ?

(a) 31
(b) 32
(c) 33
(d) 34

4 In which two compounds of the following the underlined element has the same oxidation number ?

(a) $\underline{Cr}SO_4$, $\underline{Cr}_2O_3$
(b) $Na\underline{Cl}O_3$, $Cu\underline{Cl}_2$
(c) $\underline{Mn}Cl_2$, $\underline{Mn}O_2$
(d) $\underline{S}O_3$, $H_2\underline{S}O_4$

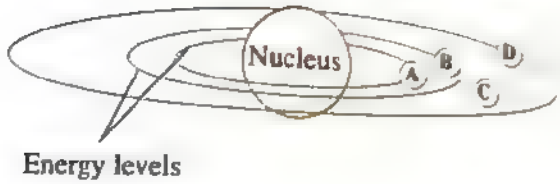
5 All the following are among the conclusions of Rutherford's experiment, <u>except</u> that ....

(a) the atom contains vast space.
(b) the nucleus is so much smaller in size than the atom.
(c) most of the atomic mass is concentrated in the nucleus.
(d) the electrons revolve around the atom in definite orbitals.

6 The maximum number of electrons required to saturate a sublevel can be estimated from the relation ....

(a) $4\ell + 2$
(b) $2\ell + 1$
(c) $2n^2$
(d) $4\ell - 2$

7 **According to the wave mechanical theory, the letter (D) in the opposite figure represents ....**



ⓐ a fixed position of the electron.

ⓑ the farthest position from nucleus that an electron can reach.

ⓒ a probable position of an electron.

ⓓ an impossible position for an electron.

8 **Among the properties of the nonmetals is that they ....**

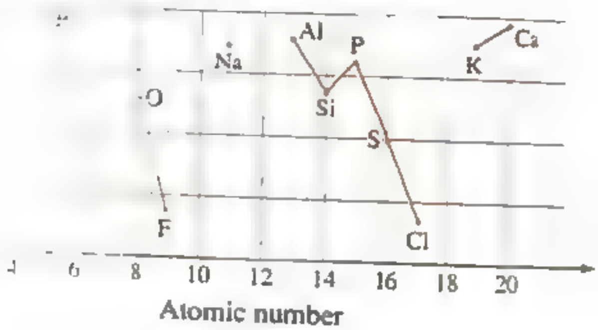
ⓐ are reducing agents.

ⓑ form oxides which react with acids.

ⓒ gain electrons forming cations.

ⓓ are electronegative elements.

9 **What is the property which is represented by the vertical axis of the opposite graph of the first 20 elements in the periodic table ?**



ⓐ Atomic radius.

ⓑ Electron affinity.

ⓒ Ionization potential.

ⓓ Electronegativity.

10 **The number of the electrons of the sublevel *d* in $_{26}Fe^{3+}$ ion equals ....**

ⓐ the number of the electrons of the sublevel *p* in $_{7}N$ atom.

ⓑ the number of the elements of the second period in the periodic table.

ⓒ the number of the sublevels in $_{27}Co^{3+}$ ion.

ⓓ the number of the electrons of the sublevel *p* in $_{8}O^{-}$ ion.

11 **Which of the following choices represents the correct ascending graduation in the atomic radius property ?**

Choices	Smaller radius ⟶ Larger radius		
ⓐ	Ca^{2+}	K^{+}	Ar
ⓑ	Ca^{2+}	Ar	K^{+}
ⓒ	Ar	K^{+}	Ca^{2+}
ⓓ	K^{+}	Ca^{2+}	Ar

12 Which of the following quantum numbers combinations belongs to an electron that is located in one of $4p$ orbitals ?

ⓐ $n = 4, \ell = 1, m_\ell = 0, m_s = +\frac{1}{2}$

ⓑ $n = 4, \ell = 1, m_\ell = +3, m_s = -\frac{1}{2}$

ⓒ $n = 4, \ell = 2, m_\ell = 0, m_s = +\frac{1}{2}$

ⓓ $n = 4, \ell = 4, m_\ell = +3, m_s = -\frac{1}{2}$

13 What are the two elements in which electronegativity of the second element is higher than the electronegativity of the first element ?

Choices	First element	Second element
ⓐ	F	Fe
ⓑ	Br	Cl
ⓒ	Li	K
ⓓ	S	P

14 Number of electrons equals number of neutrons in ....

ⓐ ${}^{11}_{5}B$

ⓑ ${}^{23}_{11}Na^{+}$

ⓒ ${}^{24}_{12}Mg^{2+}$

ⓓ ${}^{19}_{9}F^{-}$

15 Which of these choices represents the electron configuration of boron element ?

Choices	$1s$	$2s$	$2p_x$	$2p_y$	$2p_z$
ⓐ	↑↓	↑↓	↑		
ⓑ	↑	↑↓	↑	↑	
ⓒ	↑↓	↑	↑		
ⓓ	↑↓	↑↑	↑		

16 Each of the following reactions is an oxidation–reduction reaction, except ....

ⓐ $Cu + Br_2 \longrightarrow CuBr_2$

ⓑ $CO + H_2O \longrightarrow CO_2 + H_2$

ⓒ $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

ⓓ $RbOH + HCl \longrightarrow RbCl + H_2O$

17 Each of the following oxides reacts with sodium hydroxide solution to form a salt, __except__ ....

(a) Al_2O_3

(b) P_2O_5

(c) MgO

(d) SiO_2

18 The photon which is emitted from the electron of hydrogen atom when it transfers from *4d* to *2s* is in the form of ....

(a) infrared ray.

(b) ultraviolet ray.

(c) visible ray.

(d) X–ray.

19 Which of the following is correct for the properties of the cathode rays ?

(a) They heat a thin metal sheet that stands in their way as they move in straight lines.

(b) They move a light ball of foam as they move in straight lines.

(c) They affected by the electrical field as they [illegible] particles.

(d) They heat a thin metal sheet that stands in their way as they have thermal effect.

20 Protactinium is one of the actinides and its electronic configuration is ....

(a) [Xe], $6s^2$, $5d^0$, $4f^6$

(b) [Xe], $6s^2$, $5d^3$, $4f^{14}$

(c) [Rn], $7s^2$, $6d^1$, $5f^2$

(d) [Rn], $7s^2$, $6d^4$, $5f^{14}$

21 What is the maximum number of electrons which have the spin quantum number ($m_s = +\frac{1}{2}$) in the sublevel ($\ell = 3$) ?

(a) 3

(b) 5

(c) 6

(d) 7

22 The opposite table shows the first five ionization potentials of the element (X).

Deduce the formula of the chloride of the element (X).

Ionization potential (kJ/mol)				
First	Second	Third	Fourth	Fifth
+738	+1450	+7733	+10543	+13630

....

....

.... 1 mark

23 The reaction of acid with sodium carbonate salt is indicated by the evolution of CO_2 gas bubbles, so if two equal volumes of H_2SO_4 and H_2ClO_3 acids with similar concentrations are added to two similar masses of sodium carbonate.

Deduce the name of the acid which forms the higher number of bubbles in the beginning of the reaction, with **proving your answer with a scientific proof in the light of what you have studied.**

....

....

....

....

....

.... 2 marks

24 **Calculate the difference in the number of the representative elements** between the first period and the second period in the modern periodic table.

....

....

....

....

....

.... 1 mark

25 **The following table illustrates some informations about the elements (X), (Y) :**

	Element (X)	Element (Y)
Quantum numbers of the last electron in the element atom	$(n = 1 , \ell = 0, m_\ell = 0 , m_s = +\frac{1}{2})$	$(n = 2 , \ell = 1, m_\ell = +1 , m_s = +\frac{1}{2})$
Bond length in the element molecule	0.6 Å	1.4 Å
Electronic configuration of the element	.... (1)	.... (2) ....

(1) **Complete** the previous table with the electronic configurations of the elements (X) and (Y).

(2) **Predict** the bond length of the molecule of the element which precedes the element (Y) in the periodic table.

....

2 marks

26 Two electrons in one element atom are located in the [illegible] the same *p* sublevel in the principal level L

Write the quantum numbers of the two electrons

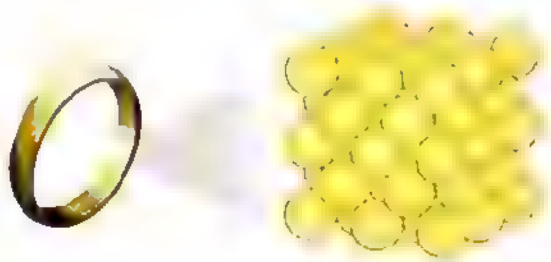
....

....

....

1 mark

27 **The opposite figure represents one of the postulates of an atomic theory that you have studied :**



(1) **What** is this theory ?

....

(2) **What** is the postulate which is represented in this figure ?

....

....

2 marks

Choose the correct answer for the questions 1 : 21 .

21 marks

1 What is the number of the natural noble gases in which *1s* orbital is filled with electrons ?

(a) 1
(b) 3
(c) 5
(d) 6

2 What is the reducing agent in the redox reaction which is represented by the following equation $12H^+_{(aq)} + 2IO^-_{3(aq)} + 10Fe^{2+}_{(aq)} \longrightarrow 10Fe^{3+}_{(aq)} + I_{2(s)} + 6H_2O_{(l)}$?

(a) I_2
(b) H^+
(c) Fe^{2+}
(d) IO_3^-

3 A student represented the electron configuration of oxygen atom in its ground state as follows : $1s^2$, $2s^2$, $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{}$ $2p$

This representation violates ....

(a) Hund's rule only.
(b) Aufbau principle only.
(c) Pauli's exclusion principle on
(d) Hund's rule and Pauli's princi

4 All the following sets of quantum numbers are possible, <u>except</u> ....

(a) $n = 4$, $\ell = 3$, $m_\ell = -2$, $m_s = -\frac{1}{2}$
(b) $n = 5$, $\ell = 3$, $m_\ell = +2$, $m_s = -\frac{1}{2}$
(c) $n = 3$, $\ell = 2$, $m_\ell = -1$, $m_s = +\frac{1}{2}$
(d) $n = 1$, $\ell = 1$, $m_\ell = +1$, $m_s = +\frac{1}{2}$

5 A sample of a compound formed by the combination of 2.69 g of hydrogen with 47.31 g of sulphur.

What is the mass of hydrogen in a sample of the same compound in which the mass of sulphur equals 75.63 g ?

(a) 2.69 g
(b) 1.68 g
(c) 4.3 g
(d) 203.4 g

6. The two ions $_{27}W^{2+}$ and $_{28}X^{3+}$ are similar in all the following, except ....

ⓐ the number of protons which exist in the nucleus of the atom.
ⓑ the number of electrons of the last principal level.
ⓒ the number of the sublevels which are occupied by electrons.
ⓓ the number of the unpaired electrons in the last sublevel.

7. The relation between the electron affinity of sulphur and that of oxygen resembles the relation between the electron affinity of chlorine and that of fluorine.
Which of these choices represents the correct descending graduation in electron affinity in nitrogen, oxygen and sulphur ?

ⓐ $S > O > N$
ⓑ $O > S > N$
ⓒ $N > O > S$
ⓓ $S > N > O$

8. Neutral oxides react neither with acids nor with bases.
Which of the following substances are neutral oxides ?

ⓐ NO_2 , Na_2O
ⓑ CO , NO
ⓒ SnO , K_2O
ⓓ CO_2 , NO_2

9. The element whose atomic number is 57 belongs to ....

ⓐ s-block.
ⓑ p-block.
ⓒ d-block.
ⓓ f-block.

10. The opposite table shows the quantum numbers (n), (ℓ) of 5 electrons in one atom.
What is the correct ascending order of the energies of these electrons ?

Electron	(I)	(II)	(III)	(IV)	(V)
(n)	3	5	4	4	4
(ℓ)	2	0	1	2	0

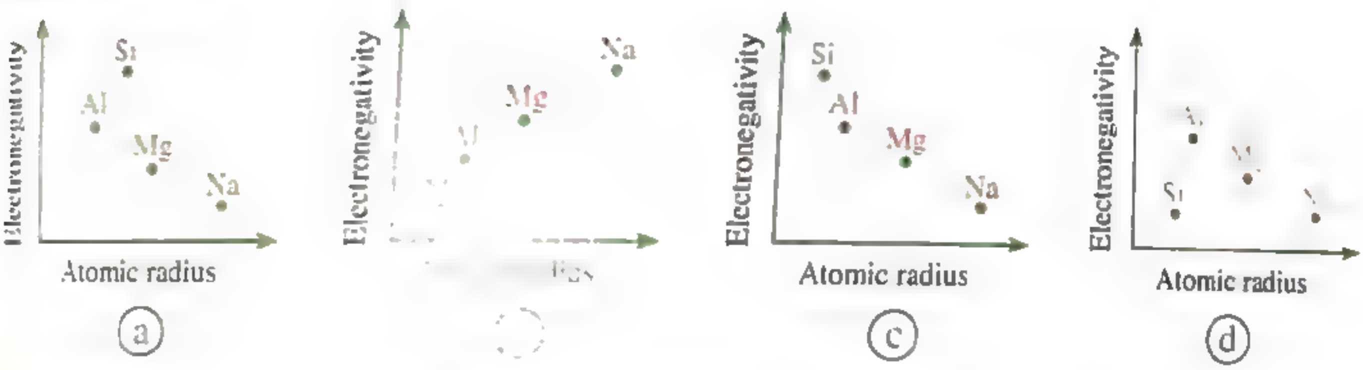
ⓐ I < V < III < IV < II
ⓑ I < V < III < II < IV
ⓒ V < I < III < II < IV
ⓓ V < I < II < III < IV

11 In the ... $_2 \longrightarrow SO_3 + F_2$

Which is being oxidized and which is reduced in this reaction ?

Choices	Fluorine	Oxygen in OF_2	Sulphur
(a)	Oxidized	Oxidized	Reduced
(b)	Oxidized	Reduced	Oxidized
(c)	Reduced	Oxidized	Reduced
(d)	Reduced	Reduced	Oxidized

12 Which of the following graphical figures represents the relation between electronegativity of (sodium, magnesium, aluminum and silicon) and their atomic radii ?



13 The concept of the atom as the smallest unit of matter was adopted by ....

(a) Democritus and Aristotle.
(b) Boyle and Aristotle.
(c) Democritus and Thomson.
(d) Bohr and Berzelius.

14 The line spectrum differs from an element to another due to ....

(a) the difference in the number of neutrons in each of them.
(b) the difference in the mass number of each of them.
(c) the difference in the electronic configuration of each of them.
(d) the difference in the number of valence electrons in each of them.

15 All the following match Bohr's atomic model, except ....

(a) the line spectrum of hydrogen atom.
(b) Pauli's principle.
(c) Planck's theory.
(d) Heisenberg's principle.

16 The oxide ion $^{16}_{8}O^{2-}$ contains ....

(a) 8 protons , 10 electrons.
(b) 10 protons , 8 electrons.
(c) 8 protons , 9 electrons.
(d) 10 protons , 7 electrons.

17 **The metal which is less active than potassium but more active than lithium and beryllium is ....**

ⓐ Na

ⓑ Ca

ⓒ B

ⓓ Fr

18 **All the following about the periodic table are correct, <u>except</u> .. ..**

ⓐ it consists of number of groups more than double the number of periods.

ⓑ the alkali elements differ in the principal quantum number (n).

ⓒ the energy sublevels are filled with electrons according to the uncertainty principle.

ⓓ Pauli's principle is applied to every element in the periodic table.

19 **What is the total number of valence electrons in thiosulphate ion $(S_2O_3)^{2-}$?**

ⓐ $28e^-$

ⓑ $30e^-$

ⓒ $32e^-$

ⓓ $34e^-$

20 **What are the two quantum numbers which represent the orbitals that are filled successively with electrons in the elements $_{21}Sc$ to $_{30}Zn$?**

ⓐ $(n = 3 , \ell = 1)$

ⓑ $(n = 3 , \ell = 2)$

ⓒ $(n = 4 , \ell = 1)$

ⓓ $(n = 4 , \ell = 2)$

21 **What is the number of the orbitals which are completely filled with electrons in the principal level (n = 3) of iodine atom $_{53}I$?**

ⓐ 9

ⓑ 10

ⓒ 11

ⓓ 12

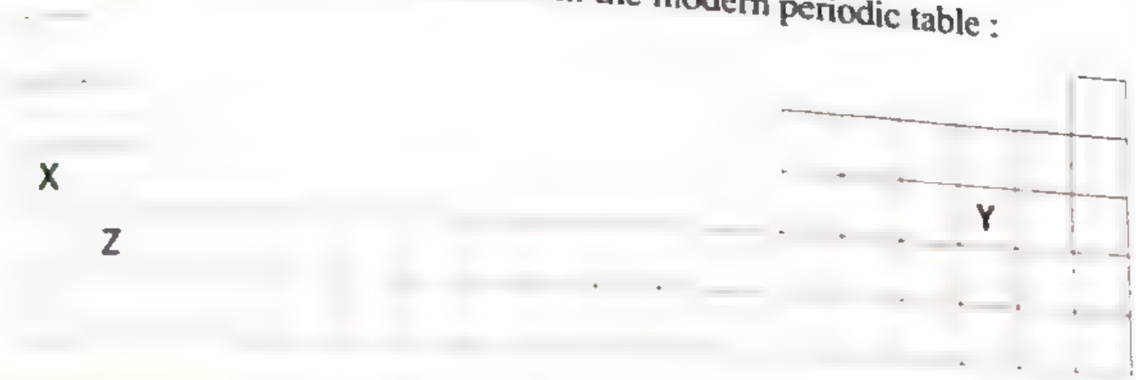
22 Determine the location of the element (X) in the periodic table, knowing that the quantum numbers of its last electron are : $(n = 3 , \ell = 1 , m_\ell = -1 , m_s = -\frac{1}{2})$

....

....

1 mark

23 The following figure represents a section in the modern periodic table :



Which of the elements X, Y and Z has the highest second potential energy ? Explain.

....

....

....

....

....

....

....

2 marks

24 Explain in the light of what you have studied,

which is more acidic sulphuric acid H_2SO_4 or sulphurous acid H_2SO_3 ?

....

....

....

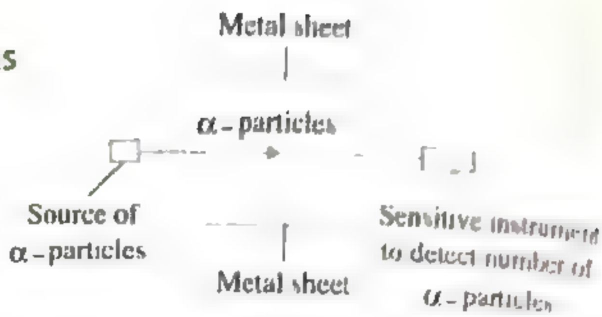
....

....

....

....

25 The opposite figure represents the path of a beam of α-particles between two metal sheets in vacuum conditions :



(1) **Illustrate** on the figure the path of the beam of α-particles if the upper metal sheet becomes negatively charged and the lower metal sheet becomes positively charged.

(2) **Predict** what will happen to the reading of the sensitive instrument after charging the two metal sheets with different charges.

....

2 marks

26 Chlorine atomic radius equals 0.99 Å, the bond length in the molecule of ammonia equals 1 Å, and the bond length in the molecule of hydrogen chloride equals 1.29 Å
Calculate which is longer, the bond in hydrogen chloride or the bond in nitrogen molecule.

....
....
....
....
....
....

1 mark

27 The following series of elements is located in one of the modern periodic table periods :

Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
$4s^2, 3d^1$	$4s^2, 3d^2$	$4s^2, 3d^3$	....	$4s^2, 3d^5$	$4s^2, 3d^6$	$4s^2, 3d^7$	$4s^2, 3d^8$	....	$4s^2, 3d^{10}$

Complete the blanks which are found below Cr, Cu elements with what is suitable for each of them.

1 mark

Choose the correct answer for the questions **1** : **21** .

21 marks

1 **Which of the following represents the proper graduation in electron affinity ?**

ⓐ O > C > N > B

ⓑ B > N > C > O

ⓒ O > C > B > N

ⓓ O > B > C > N

2 **Breaking (M – O) bond in M – O – H indicates that ....**

ⓐ the difference in electronegativity between M and O is lower than that between O and H

ⓑ the compound is being ionized according to the reaction medium.

ⓒ the difference in electronegativity between M and O is higher than that between O and H

ⓓ the compound is being ionized as an acid.

3 **Bohr's atomic model can be applied to ....**

ⓐ Na^{10+} ion.

ⓑ He atom.

ⓒ Be^{2+} ion.

ⓓ C^{6+} ion.

4 **Which of the following conversions shows an oxidation and a reduction for the same element ?**

ⓐ $N_2 \longrightarrow NH_3 \longrightarrow NO$

ⓑ $C \longrightarrow CO \longrightarrow CO_2$

ⓒ $PbO_2 \longrightarrow PbO \longrightarrow Pb$

ⓓ $C_2H_2 \longrightarrow C_2H_4 \longrightarrow C_2H_6$

5 **What is the number of the orbitals which $(n + \ell)$ of its electrons is less than 5 ?**

ⓐ 4

ⓑ 8

ⓒ 9

ⓓ 10

6 **Which of these electron configurations is incompatible with both exclusion principle and Hund's rule ?**

ⓐ [⇅] [↓][↓][↓]

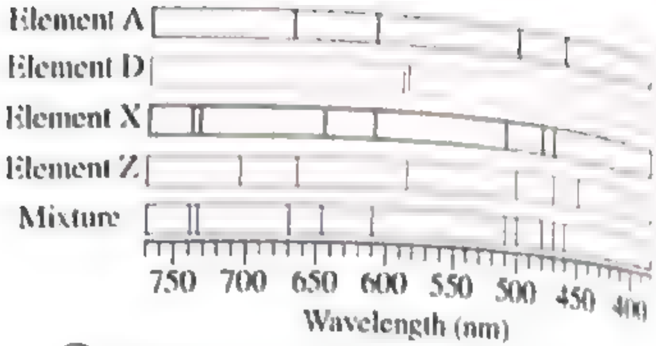
ⓑ [⇅] [⇅][⇅][↑]

ⓒ [⇅] [⇅][⇅][ ]

ⓓ [⇅] [⇈][⇅][ ]

7 The opposite figure represents the line spectra of four elements A , D , X , and Z , and of a mixture of two of these elements.

What are these two elements ?



(a) D and A (b) X and A

(c) D and Z (d) X and Z

8 Which of the following represents correctly the relation between fluorine and chlorine atoms ?

(a) $F_{(g)} < Cl_{(g)}$ regarding the energy released from each of them on gaining an electron.

(b) F < Cl regarding the ability of each of them to attract the electrons of H – X bond.

(c) Cl < F regarding half the distance between the two atoms of the molecule of each of them.

(d) Cl < F regarding the subsidiary [illegible] number of the last electron in each of them.

9 The last principal energy level in [illegible] X (n = 5) contains 5 electrons.

What is the type of its oxide X_2O_3

(a) Acidic. (b) Neutral.

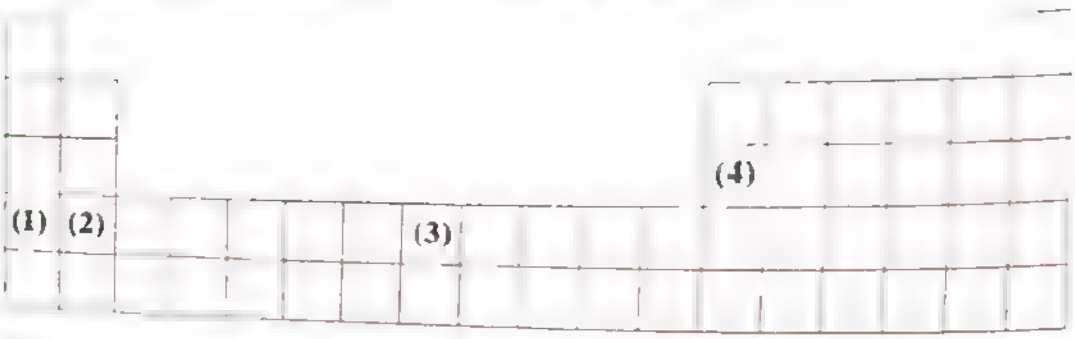
(c) Basic. (d) Amphoteric.

10 Which of the following represents the correct graduation in the atomic radius ?

(a) F > Cl > S (b) S > F > Cl

(c) Cl > S > F (d) S > Cl > F

11 The following figure represents a section in the periodic table :



What is the number of the element (X), which is characterized by a large atomic radius and good electric conductivity, and forms with chlorine XCl_2 and XCl_3 compounds ?

(a) (1) (b) (2) (c) (3) (d) (4)

12. (P) and (Q) are two atoms of two different elements :

- Number of protons in atom (P) is less than that in atom (Q) by 9
- Number of unpaired electrons in atom (P) is more than that in atom (Q) by 1

What does this indicate about the elements (P) and (Q) ?

ⓐ Element (P) is carbon and element (Q) is phosphorus only.

ⓑ Element (P) is nitrogen and element (Q) is sulphur only.

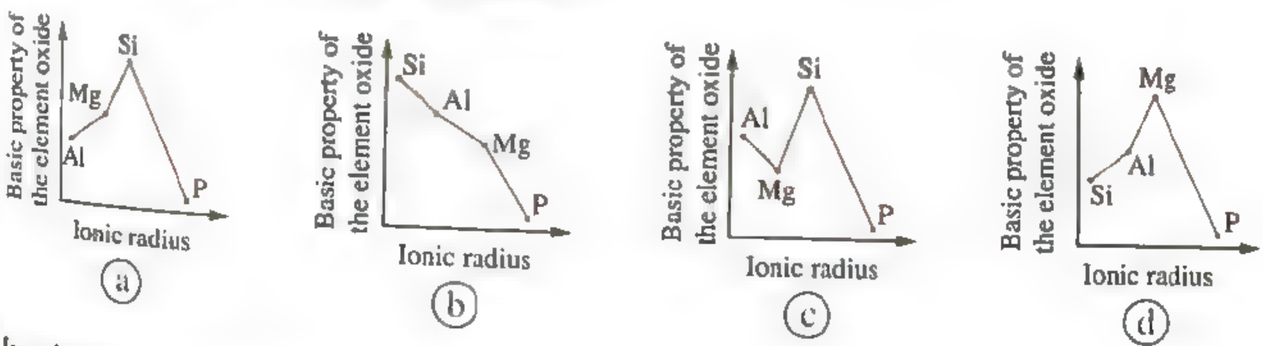
ⓒ Elements (P) and (Q) may be carbon and phosphorus or oxygen and chlorine.

ⓓ Elements (P) and (Q) may be nitrogen and sulphur or oxygen and chlorine.

13. What is the number of the sublevels and that of the orbitals which are occupied by electrons in an ion of a metal whose electron configuration ends with the sublevel $(2p^6)$?

Choices	Number of sublevels	Number of orbitals occupied by electrons
ⓐ	6	5
ⓑ	5	3
ⓒ	5	7
ⓓ	3	5

14. Which of the following graphs represents the relation between the basic property of the element oxide and its ionic radius ?



15. In which of the following pairs of substances do the nitrogen atoms have the same oxidation state ?

ⓐ HNO_3 , N_2O_5

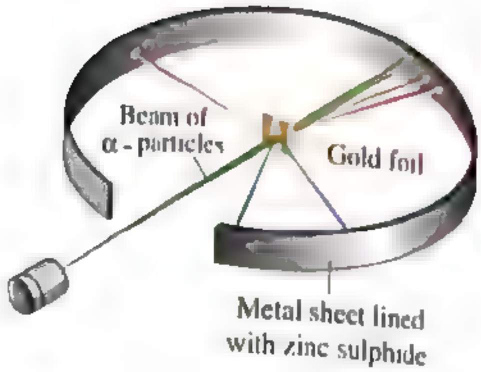
ⓑ NO , HNO_2

ⓒ N_2 , N_2O

ⓓ HNO_2 , HNO_3

16 **In the experiment which is illustrated in the opposite figure.**

What is the postulate which could not be concluded from this experiment ?



(a) The atom is not solid.

(b) The atom contains a positively charged part.

(c) It is possible that the electrons are present in the electron cloud which surrounds the nucleus.

(d) The dense part in the atom occupies a tiny space.

17 **The following table shows the first seven ionization potentials of the element (X) :**

Ionization potentials (kJ/mol)						
First	Second	Third	Fourth	Fifth	Sixth	Seventh
+870	+1800	+3000	+3600	+5800	+7000	+13200

Which of the following statements is true for the element (X) ?

(a) It contains a half filled *p* sublevel.

(b) It forms with beryllium a compound whose formula is BeX_2

(c) It is located in the fourth period in the periodic table.

(d) It has a first ionization potential less than that of the element which precedes it in the periodic table.

18 **The actual path of the last electron in sodium atom cannot be precisely determined, the previous statement is an application of ....**

(a) Hund's rule.

(b) uncertainty principle.

(c) Bohr's rule.

(d) the dual nature of electron.

19 **The electronic configuration of molybdenum element $_{42}Mo$ is ....**

(a) [Kr] , $5s^1$, $4d^{10}$

(b) [Kr] , $5s^2$, $4d^4$

(c) [Kr] , $5s^1$, $4d^5$

(d) [Kr] , $5s^2$, $4d^5$

20 **Which of the following includes an orbital of *3d* sublevel that contains one pair of electrons, while its *4s* sublevel is completely filled with electrons ?**

(a) $_{29}Cu$

(b) $_{26}Fe$

(c) $_{28}Ni^{2+}$

(d) $_{38}Sr^{2+}$

21 Arsenic atom $_{33}As$ gains 3 electrons when it combines with sodium to form Na_3As

What are the four quantum numbers of the first electron of these gained electrons ?

(a) $n = 4$, $\ell = 0$, $m_\ell = -1$, $m_s = -\frac{1}{2}$

(b) $n = 4$, $\ell = 1$, $m_\ell = -1$, $m_s = -\frac{1}{2}$

(c) $n = 3$, $\ell = 0$, $m_\ell = 0$, $m_s = +\frac{1}{2}$

(d) $n = 3$, $\ell = 1$, $m_\ell = -1$, $m_s = -\frac{1}{2}$

22 What is the block in the periodic table in which most of the metallic elements are located ?

....

.... 1 mark

23 The only compound that Dalton knew the ratios of its components was water (as in the table). he thought that the ratio between the number of hydrogen atoms to the number of oxygen atoms, equals 1 : 1

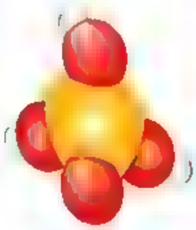
Oxygen	Hydrogen
87%	13%

What is the molecular formula of water as Dalton thought ?

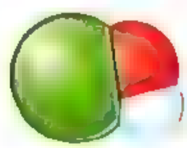
....

.... 1 mark

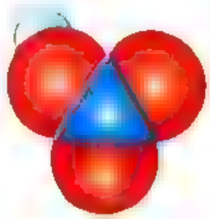
24 Arrange the following oxygenated acids ascendingly according to their strength :



Acid (1)



Acid (2)



Acid (3)

....

.... 1 mark

25 Classify the elements which have the following electronic configurations into two groups, with mentioning the type of the elements of each group :

(1) $1s^2, 2s^2, 2p^5$

(2) $1s^2, 2s^1$

(3) $1s^2, 2s^2, 2p^6$

(4) $1s^2, 2s^2, 2p^6, 3s^2, 3p^5$

(5) $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^1$

(6) $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^6$

2 marks

26 Show the oxidation and the reduction processes [illegible] the following equation, with determining the oxidizing agent [illegible] agent :

$$2P + 5HClO + 3H_2O \longrightarrow 2H\ [illegible]$$

2 marks

27 A representative element contains four principal energy levels occupied by electrons and the last energy sublevel contains three unpaired electrons. Calculate the number of :

(1) The orbitals which are completely filled with electrons.

(2) The electrons required to convert this element to an ion with an electronic configuration similar to the noble gas which follows it.

2 marks

Open Book Exam model 11

Answered

Rate your level

Superior from marks to marks | Remarkable from marks to marks | from marks to marks | Weak less than 15 marks

- Choose the correct answer for the questions 1 : 21 . 21 marks

1 • The first assumption : Matter can not be divided infinitely.
• The second assumption : Matter is able to be changed infinitely.
Who were the first to assume these assumptions ?

Choices	First assumption	Second assumption
(a)	Schrödinger	Heisenberg
(b)	Bohr	Boyle
(c)	Dalton	Rutherford
(d)	Democritus	Aristotle

2 All the following sets of quantum numbers are possible, except ....

(a) $n = 3 , \ell = 2 , m_\ell = -2 , m_s = -$
(b) $n = 4 , \ell = 0 , m_\ell = 0 , m_s = -\frac{1}{2}$
(c) $n = 3 , \ell = 2 , m_\ell = -3 , m_s = +\frac{1}{2}$
(d) $n = 5 , \ell = 3 , m_\ell = 0 , m_s = -\frac{1}{2}$

3 Which of the following sublevels can absorb a photon but can not lose one ?

(a) 3d (b) 2p (c) 1s (d) 2s

4 Which of these elements can have positive or negative oxidation number in its compounds ?

(a) Cesium. (b) Fluorine.
(c) Iodine. (d) Krypton.

5 Assuming disregarding aufbau principle.
What is the block which calcium element would belong to ?

(a) s-block. (b) p-block.
(c) d-block. (d) f-block.

6. Two aqueous solutions, which are :

- The first : $M_1 - O - H$
- The second : $M_2 - O - H$

If the electronegativities of the elements are : $[M_1 = 3.4 , M_2 = 1.2 , O = 3.5 , H = 2.1]$.

What are the types of the two solutions ?

Choices	First solution	Second solution
(a)	Acidic	Basic
(b)	Acidic	Acidic
(c)	Basic	Acidic
(d)	Basic	Basic

7. What is the electron configuration of the valence electrons of the element whose atomic number is 23 ?

(a) $3d^5$

(c) $3d^2 , 4s^1 , 4p^1$

8. Metals which are located in the beginning of each period are characterized by ....

(a) small atomic radius.
(b) high ionization potential.
(c) high electronegativity.
(d) low ionization potential.

9. What is the maximum number of electrons that have the quantum numbers $(n = 3), (\ell = 2)$?

(a) 2
(b) 8
(c) 10
(d) 18

10. Which of the following elements is the strongest reducing agent ?

(a) Al
(b) Mg
(c) Zn
(d) Cu

11. What is the equation which represents the first ionization potential of barium ?

(a) $Ba_{(s)} \longrightarrow Ba^+_{(g)} + e^-$
(b) $Ba^+_{(g)} \longrightarrow Ba^{2+}_{(g)} + e^-$
(c) $Ba^{2+}_{(g)} + e^- \longrightarrow Ba^+_{(g)}$
(d) Ba

12 (X) and (Y) are two different elements in the third period in the periodic table, so if :

- The oxide of the element (X) is insoluble in water but it reacts with each of NaOH and HCl
- The chloride of the element (Y) is soluble in water forming colourless acidic solution.

Which of the following choices represents the elements (X) and (Y) ?

Choices	Element (X)	Element (Y)
(a)	Al	P
(b)	Al	Zn
(c)	Mg	P
(d)	Mg	Si

13 The element (Q) forms an ion having the following properties :

- Has the same electron config[illegible] the noble gas which precedes it in the periodic table.
- Number of its protons is higher than that of its electrons.
- Formed by losing electrons fr[illegible]

Which of the following elem[illegible] the element (Q) ?

(a) Aluminum ($_{13}Al$).
(b) Calcium ($_{20}Ca$).
(c) Copper ($_{29}Cu$).
(d) Sulphur ($_{16}S$).

14 The first ionization potential of element (Y) is higher than that of element (X).

What are the two elements (X) and (Y) ?

Choices	Element (X)	Element (Y)
(a)	$_{12}Mg$	$_{13}Al$
(b)	$_{7}N$	$_{8}O$
(c)	$_{10}Ne$	$_{11}Na$
(d)	$_{19}K$	$_{11}Na$

15 What is the reducing agent in the reaction : $H_2S + I_2 \longrightarrow S + 2H^+ + 2I^-$?

(a) H_2S
(b) I_2
(c) S
(d) H^+

16 **Which of the following statements represents properly the effective nuclear charge ?**

ⓐ It decreases in the same period in the periodic table by increasing the atomic number.

ⓑ It increases in the same period in the periodic table with moving from left to right.

ⓒ It does not change in the same period in the periodic table by increasing the atomic number.

ⓓ It increases then decreases in the same period in the periodic table with moving from left to right.

17 **Which of the following choices states the types of lithium and magnesium elements ?**

Choices	Lithium	Magnesium
ⓐ	Nonmetal	Metal
ⓑ	Nonmetal	Nonmetal
ⓒ	Metal	Metal
ⓓ	Metalloid	Metalloid

18 **Which of the following choices represents the electron affinity of chlorine ?**

ⓐ $Cl^-_{(g)} \longrightarrow Cl^+_{(g)} + e^-$

ⓑ [illegible] $\longrightarrow Cl^-_{(g)}$

ⓒ $Cl^-_{(g)} \longrightarrow Cl^{2-}_{(g)} + e^-$

ⓓ [illegible] $\longrightarrow Cl^-_{(g)} + e^-$

19 **The opposite figure represents a section in the periodic table.**

Which of the following groups its elements exist as monatomic gases ?

ⓐ X

ⓑ Y

ⓒ Z

ⓓ W

20 **What is the electronic configuration of the first element in p-block in the fourth period in the periodic table ?**

ⓐ [Ar] , $4s^2$, $3d^{10}$, $4p^1$

ⓑ [Ar] , $4s^1$

ⓒ [Kr] , $5s^2$, $4d^{10}$, $5p^1$

ⓓ [Kr] , $5s^1$

21 In 1806, the scientist Joseph Proust found that a given chemical compound always contains its components in a fixed ratio (by mass), he called that belief the law of definite proportion.

What is the atomic theory which explained the law of definite proportion simply ?

(a) Dalton's atomic theory.

(b) Thomson's atomic theory.

(c) Bohr's atomic theory.

(d) Rutherford's atomic theory.

22 Was Pauli's principle applied to the distribution of the electrons in the following orbitals ? Explain.

....

2 marks

23 Why is it difficult to obtain M⁻ ... the element which is located in the third period, group (1A) ?

....

....

....

....

1 mark

24 Illustrate the oxidizing agent and the reducing agent in the reaction which is represented by the equation : $6H^+ + 6I^- + ClO_3^- \longrightarrow 3I_2 + 3H_2O + Cl^-$

....

....

....

1 mark

25 The opposite figures show two different perceptions of the movement of the electrons around the nucleus.
Which of them assumes the possibility of determining the position of the electron precisely ? To whom this assumption is attributed ?

(1)

(2)

....

1 mark

26 A representative element (M) whose electrons are distributed in 2 principal levels, and the last sublevel contains 3 unpaired electrons :

(1) **Determine** the location of this element in the modern periodic table.

....

....

(2) **What** is the block of this element ?

....

2 marks

27 The following figure illustrates a section in the modern periodic table :

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe

(1) **What** is the number of the representative elements in this section ?

....

(2) **Write** the electronic configuration of Ge

....

2 marks

Open Book Exam model 12

Answered

Rate your level

Superior	Remarkable	above average	Weak
from 30 marks to 27 marks	from 26 marks to 21 marks	from .. marks to .. marks	less than 15 marks

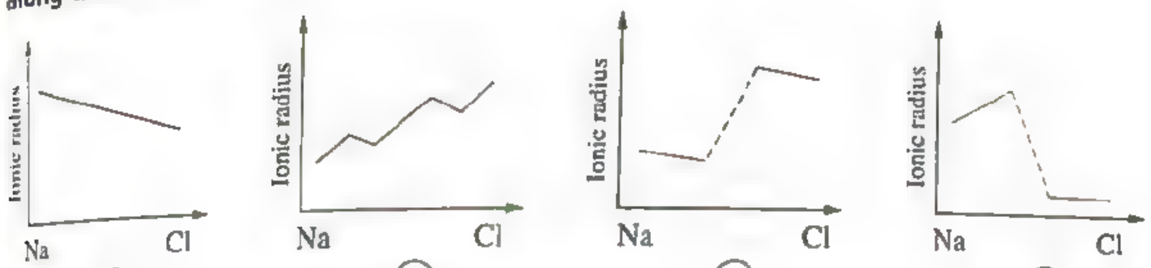
Choose the correct answer for the questions (1) : (21) . 21 marks

1 What is the electron configuration which is consistent with Pauli's principle ?

ⓐ $1s^2, 2s^2, 2p^7$ ⓑ $1s^2, 2s^2, 2p^6, 3s^3$

ⓒ $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{12}$ ⓓ $1s^2, 2s^2, 2p^6, 3s^2, 3p^6$

2 Which of the following graphical figures represents the change in the ionic radius along the third period elements from Na to Cl ?



ⓐ ⓑ ⓒ ⓓ

3 The following reaction represents the total reaction in the rechargeable nickel-cadmium battery : $Cd + 2NiOOH + 4H_2O \longrightarrow Cd(OH)_2 + 2Ni(OH)_2.H_2O$

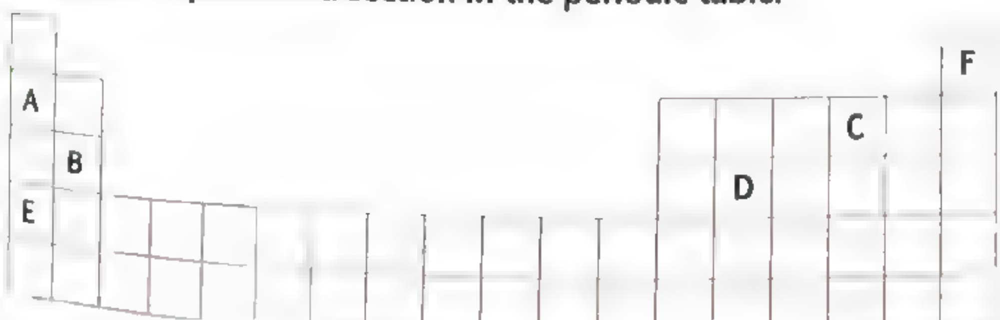
What are the oxidation numbers of nickel before the beginning of the reaction and at the end of it respectively ?

ⓐ +1.5 , +2 ⓑ +2 , +3 ⓒ +3 , +4 ⓓ +3 , +2

4 What is the least principal quantum number (n) of the two electrons in the first orbital in *d* sublevel ?

ⓐ 1 ⓑ 2 ⓒ 3 ⓓ 4

5 The following figure represents a section in the periodic table.



What is the choice which represents the movement from a metal to a metalloid ?

ⓐ A ⟶ E ⓑ E ⟶ A ⓒ A ⟶ C ⓓ B ⟶ D

6 **Which of the following elements has the highest electronegativity ?**

ⓐ Aluminum.
ⓑ Silicon.
ⓒ Phosphorus.
ⓓ Sulphur.

7 **Which of the following choices is correct ?**

Choices	$Cl_{(g)} \longrightarrow Cl^-_{(g)}$	$Cl^-_{(g)} \longrightarrow Cl_{(g)}$	$Cl_{(g)} \longrightarrow Cl^+_{(g)}$	$Cl^+_{(g)} \longrightarrow Cl^{2+}_{(g)}$
ⓐ	Electron affinity	Ionization potential	–	–
ⓑ	–	Ionization potential	Ionization potential	–
ⓒ	Electron affinity	–	–	Ionization potential
ⓓ	–	–	Ionization potential	Electron affinity

8 **Which of the following represents Rutherford's experiment ?**

ⓐ When a beam of beta particles falls on a gold sheet, it is absorbed.
ⓑ When a beam of gamma rays falls on a gold sheet, it liberates electrons.
ⓒ When a beam of helium atoms falls on a gold sheet, it is deflected.
ⓓ When a beam of helium nuclei falls on a gol[illegible]eflected.

9 **The two electrons of the same orbital in any [illegible] in the quantum number ....**

ⓐ m_s
ⓑ m_ℓ
ⓒ ℓ
ⓓ n

10 **What is the number of electrons which have the quantum numbers (n = 3), (ℓ = 2) in iron atom ?**

ⓐ 2
ⓑ 4
ⓒ 6
ⓓ 8

11 **Bohr's theory of the atomic structure agrees with the modern atomic theory on that ....**

ⓐ the electrons move in the orbitals around the nucleus.
ⓑ the electrons lose energy when they transfer from the principal level (n + 2) to the principal level (n).
ⓒ the orbital cannot be occupied by more than 2 electrons.
ⓓ the energies of the sublevels in the same principal level are different.

12 Which of the following choices represents the electron configuration of the atom and the two ions of copper in the stable state ?

Choices	Cu	Cu^+	Cu^{2+}
(a)	[Ar], $4s^1$, $3d^{10}$	[Ar], $3d^{10}$	[Ar], $3d^9$
(b)	[Ar], $4s^2$, $3d^9$	[Ar], $4s^1$, $3d^9$	[Ar], $3d^9$
(c)	[Ar], $4s^1$, $3d^{10}$	[Ar], $4s^1$, $3d^9$	[Ar], $4s^1$, $3d^8$
(d)	[Ar], $4s^2$, $3d^9$	[Ar], $4s^2$, $3d^8$	[Ar], $4s^2$, $3d^7$

13 Which of the following equations represents the second ionization potential of oxygen ?

(a) $O_{(g)} \longrightarrow O^{2+}_{(g)} + 2e^-$

(b) $O_{(g)} \longrightarrow O^+_{(g)} + e^-$

(c) $O^-_{(g)} + e^- \longrightarrow O^{2-}_{(g)}$

(d) $O^+_{(g)} \longrightarrow O^{2+}_{(g)} + e^-$

14 Why does the absorption spectrum of hydrogen contain separate lines ?

(a) Because there are certain energy levels in which the electron is allowed to revolve.

(b) Because it contains only one electron.

(c) Because it contains only one proton.

(d) Because the spectrum is recorded at low temperature.

15 The following ionic equation represents one of the chemical reactions :

$$MnO^-_{4(aq)} + 8H^+_{(aq)} + 5Fe^{2+}_{(aq)} \longrightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)} + 5Fe^{3+}_{(aq)}$$

Which of the following statements is correct ?

(a) Each Fe^{2+} ion gains 5 electrons.

(b) Each H^+ ion is oxidized.

(c) The oxidation number of Mn is changed from –1 to +2

(d) The oxidation number of Mn is changed from +7 to +2

16 What happens to the spaces between energy levels on moving from (n = 1) to (n = 7) ?

(a) Decrease by increasing (n).

(b) Do not change.

(c) Increase by increasing (n).

(d) Change irregularly.

17 On moving in group (1A) from lithium to rubidium ....

ⓐ the atomic radius decreases.

ⓑ the ionic radius increases.

ⓒ the first ionization potential increases.

ⓓ the electronegativity increases.

18 Two elements in the periodic table are symbolized hypothetically by the symbols (R) and (T), if the element (R) is located in group (4A) and the element (T) is located in group (6A).

What is the formula of the compound produced from the combination of the two elements ?

ⓐ RT

ⓑ RT_6

ⓒ RT_2

ⓓ R_2T

19 The following table represents the properties of four elements (W , X , Y and Z) in the third period in the periodic table :

Element	(W)			(Z)
Reaction with cold water	Reacts vigorously	Does not react	Reacts slowly	Reacts slowly
Reactions of the element oxide	Reacts with acids	Reacts with bases	Reacts with acids and bases	Reacts with acids

Which of the following choices represents increasing the atomic number of these elements ?

ⓐ W < X < Y < Z

ⓑ W < Z < Y < X

ⓒ Y < W < X < Z

ⓓ Z < X < Y < W

20 Each of the following can be confirmed undoubtedly, except ....

ⓐ the number of energy levels which are occupied by electrons in $_{12}Mg$ atom.

ⓑ the number of orbitals which are occupied by unpaired electrons in $_{26}Fe$ atom.

ⓒ the position and the speed of the electron in hydrogen atom at a certain moment.

ⓓ the difference of the properties of the cathode rays with the difference of the type of the substance of the cathode.

21 The two electrons which have the same l and m_l values are located in the same ....

(a) principal level.
(b) sublevel.
(c) orbital.
(d) atoms of the elements of the same period.

22 Why is the electronic configuration ($1s^2, 2s^2, 2p^7$) incorrect ?

....

....

1 mark

23 How many unpaired electrons are present in $_{27}Co^{3+}$ ion in its gaseous ground state ?

....

....

1 mark

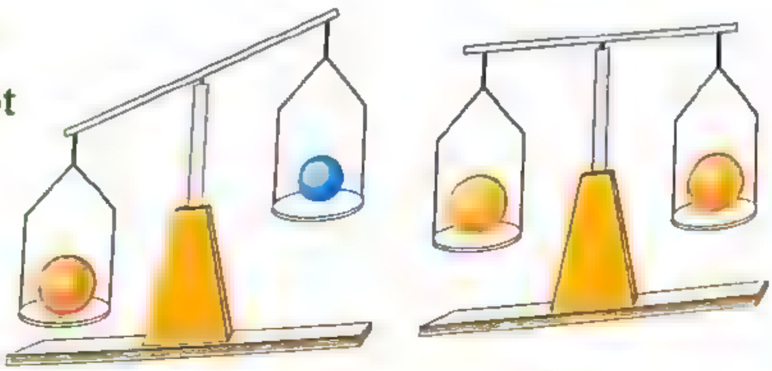
24 What are the types of the el… …ich are found in the sixth period in the periodic table ?

....

....

1 mark

25 The opposite figure represents one of the postulates of an atomic theory that you have studied :



(1) What is the name of this theory ?

....

....

(2) State the postulate represented in the figure.

....

....

2 marks

26 In the process which is represented by the following equation :

$$Zn_{(g)} + S_{(g)} \longrightarrow Zn^{2+}_{(g)} + S^{2-}_{(g)}$$

(1) **What is the name** of the required energy when $Zn_{(g)}$ is converted to $Zn^{+}_{(g)}$?

(2) **Suggest one use** for the solid substance which is produced from the combination of the previous cation and anion.

2 marks

27 Phosphoric acid H_3PO_4 is used in the [illegible] fertilizers :

(1) **Deduce** the number of oxygen atoms [illegible] with hydrogen in this acid.

(2) **Write** the balanced symbolic equation which represents the reaction of phosphoric acid with magnesium oxide.

2 marks

Open Book Exam model 13

Answered

• Choose the correct answer for the questions 1 - 21 .

1 The ability of the gases to conduct electricity can be enhanced by

(a) increasing the gas pressure as well as the potential difference between the two electrodes of the conducting tube.

(b) decreasing the gas pressure as well as the potential difference between the two electrodes of the conducting tube.

(c) decreasing the gas pressure and increasing the potential difference between the two electrodes of the conducting tube.

(d) increasing the gas pressure and decreasing the potential difference between the two electrodes of the conducting tube.

2 The energies of the differe[illegible] in the atom or ion which contains one electron depend on

(a) n only.
(b) n and ℓ only.
(c) n , ℓ and m_ℓ only.
(d) n , ℓ , m_ℓ and m_s

3 Which of the following sets of atomic numbers belongs to elements located in group 16 in the periodic table ?

(a) 8 , 16 , 32 , 54
(b) 16 , 34 , 54 , 86
(c) 8 , 16 , 34 , 52
(d) 10 , 16 , 32 , 50

4 What is the electron configuration which represents an excited atom ?

(a) $[Ne], 3s^2, 3p^6, 4s^2, 3d^4$
(b) $[Ne], 3s^2, 3p^6, 4s^1, 3d^5$
(c) $[Ne], 3s^2, 3p^6, 4s^2, 3d^1$
(d) $1s^2, 2s^2, 2p^5, 3s^1$

5 Which of the following elements atoms gains an electron with higher difficulty than others ?

(a) Radon.
(b) Nitrogen.
(c) Oxygen.
(d) Radium.

6 The opposite table shows the oxidation numbers of three elements A , B and C in a compound. What is the probable molecular formula of this compound ?

Element	A	B	C
Oxidation number	+2	+5	−2

ⓐ $A_3(B_4C)_2$
ⓑ $A_3(BC_4)_2$
ⓒ $A_2(BC_3)_2$
ⓓ ABC_2

7 Each of the following relations represents correctly one property in the elements of the periodic table, except ....

Choices	Relation	Property
ⓐ	$Fe^{3+} > Fe^{2+}$	Ionic radius
ⓑ	O > N	Second ionization potential
ⓒ	Cu > Zn	[illegible]
ⓓ	Ti > In	[illegible] ential

8 How many quanta are released when the electron in hydrogen atom jumps from (n = 4) to (n = 1) ?

ⓐ 6
ⓑ 3
ⓒ 2
ⓓ 1

9 What is the number of the points in $2p_x$ orbital in which the electron density equals zero ?

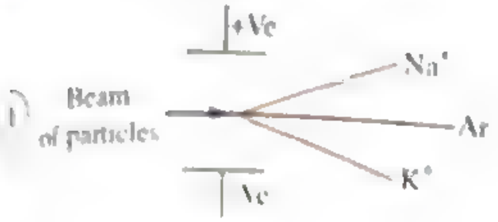
ⓐ Zero
ⓑ 1
ⓒ 2
ⓓ Infinite number.

10 Which of the following groups includes metalloids ?

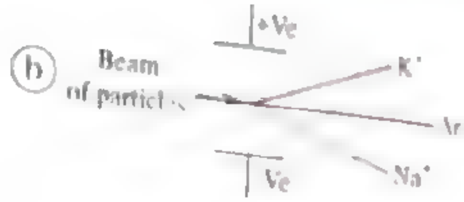
ⓐ Group 8
ⓑ Group 16
ⓒ Group 2
ⓓ Group 18

11 A beam of Na^+ , K^+ and Ar particles passes between two charged plates.
What is the correct figure which represents the effect of the charged plates on these particles ?

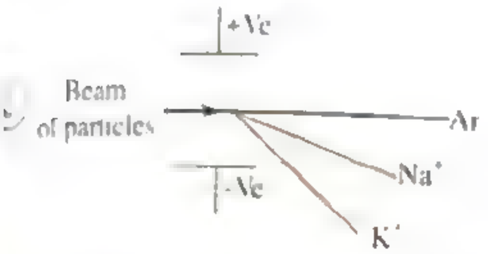
ⓐ



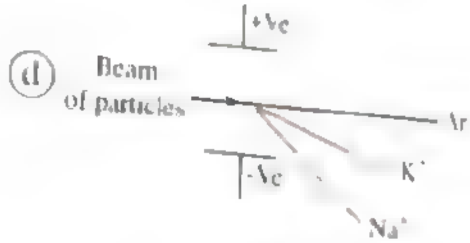
ⓑ



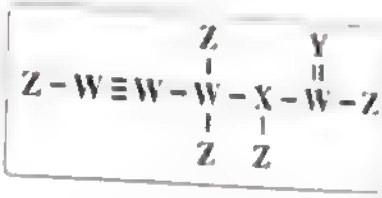
ⓒ



ⓓ



12 The opposite compound is formed of four elements W , X , Y and Z, which are located in different groups in the periodic table.
What are the numbers of the groups of this compound elements in the periodic table ?



Choices	(W)		(Y)	(Z)
ⓐ	Group (3A)	[illegible]	Group (6A)	Group (1A)
ⓑ	Group (4A)	Group (3A)	Group (6A)	Group (7A)
ⓒ	Group (3A)	Group (5A)	Group (2A)	Group (1A)
ⓓ	Group (4A)	Group (5A)	Group (6A)	Group (7A)

13 Which of the following diatomic molecules has the shortest bond length ?

ⓐ N_2 ⓑ O_2
ⓒ F_2 ⓓ S_2

14 Which of the following changes represents an oxidation process ?

ⓐ $NO_2 \longrightarrow N_2$
ⓑ $VO^{2+} \longrightarrow VO_3$
ⓒ $ClO^- \longrightarrow Cl$
ⓓ $CrO_4^{2-} \longrightarrow Cr_2O_7^{2-}$

15 **The following table represents a section in the periodic table :**

Periods	Groups							
	(1A)	(2A)	(3A)	(4A)	(5A)	(6A)	(7A)	(0)
(2)	V	W					X	
(3)	Y						Z	

Which of the following statements is correct ?

ⓐ Element (V) is more active than element (Y).

ⓑ Element (Z) is more active than element (X).

ⓒ The electronegativity of element (Y) is less than that of element (V).

ⓓ The metallic property of element (W) is stronger than that of element (V).

16 **Each of the following electron configurations is consistent with Hund's rule, <u>except</u> ....**

ⓐ [↑↓] [↑↓] [| |]

ⓑ [↑↑] [↑↓] [| |]

ⓒ [↑↓] [↑↓] [↑↓| |]

ⓓ [↑↓] [↑↓] [↑|↑|↑]

17 **What are the possible values of the quantum numbers n and m_l of an electron in one of the orbitals of *5p* sublevel ?**

ⓐ $n = 1, 2, 3, 4, 5 / m_l = +1$

ⓑ $n = 1, 2, 3, 4, 5 / m_l = -2, -1, 0, +1, +2$

ⓒ $n = 5 / m_l = -1, 0, +1$

ⓓ $n = 5 / m_l = +1$

18 **The nucleus of manganese atom Mn contains 25 protons.**

What is the electron configuration of manganese in $Mn_3(PO_4)_2$?

ⓐ [Ar] , $3d^6$

ⓑ [Ar] , $3d^5$

ⓒ [Ar] , $3d^3$, $4s^2$

ⓓ [Ar] , $3d^5$, $4s^2$

19 The opposite table represents the values of the first five ionization potentials of an element in the third period.
Which of the following illustrates the correct sequence of the orbitals from which the five electrons are lost in the different ionization processes ?

Ionization potentials (kJ/mol)				
First	Second	Third	Fourth	Fifth
+578	+1817	+2745	+11578	+14831

(a) $1s \rightarrow 2s \rightarrow 2p \rightarrow 3s \rightarrow 3p$
(b) $1s \rightarrow 1s \rightarrow 2s \rightarrow 2s \rightarrow 2p$
(c) $3p \rightarrow 3s \rightarrow 2p \rightarrow 2s \rightarrow 1s$
(d) $3p \rightarrow 3s \rightarrow 3s \rightarrow 2p \rightarrow 2p$

20 Which of these elements their number is the highest in the fourth period in the periodic table ?

(a) p-block elements.
(b) Representative elements.
(c) Transition elements.
(d) Metals.

21 What is the chemical formula of the oxygenated acid which is formed of hydrogen, bromine and oxygen elements and the ratio of (n : m) in it is (1 : 1) ?

(a) $HBrO_4$
(b) HBrO
(c) $HBrO_2$
(d) $HBrO_3$

---

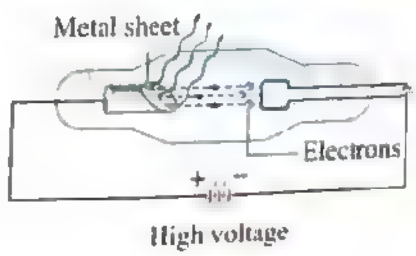
22 Calculate the bond length in a unit of lithium chloride in terms of the radii which are illustrated in the following table :

	Li	Li^+	Cl	Cl^-
The radius	1.57 Å	0.68 Å	0.99 Å	1.81 Å

....
....

1 mark

23 Does the opposite figure represent a cathode tube ? Confirm your answer with one reason from what you have studied.

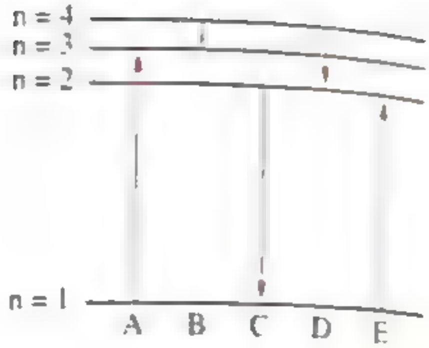


....
....

1 mark

24 The opposite figure represents the several transitions of an electron in one of the atoms.

Which of these transitions represents an emission quantum (photon) ? Explain.



25 The opposite figure represents the locations of the elements W , X , Y and Z in the periods (2) and (3) in the periodic table, the element Y reacts with chlorine forming YCl_5 compound.

Second period		W		
Third period	X		Y	Z

Answer the following :

(1) Determine the number of the group of th... ( )

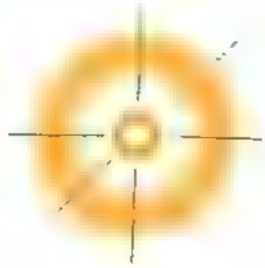
(2) What is the maximum oxidation num... in its compounds ? ( )

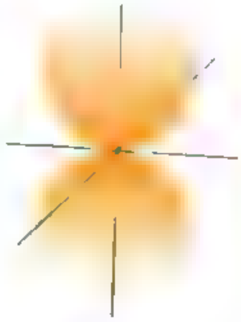
26 Study the following scheme, then a...

(1) Write the electronic configuration of the cation of the compound (Y)

(2) What is the name of compound (Z) ?

27 The following figures illustrate the possible electron cloud of the excited hydrogen electron in two different cases :


Case (1)


Case (2)

(1) **Write** the possible (l) and (m_l) values of each electron in these two cases.

....

....

(2) **What** is the principal quantum number (n) which is not possible for this electron in the two cases ?

....

.... 2 marks

Open Book Exam model 14

Answered

Rate your level

Choose the correct answer for the questions 1 : 21.

1 In the equation : $4Al + 3O_2 \longrightarrow 2Al_2O_3$ when aluminum loses 12 mol of electrons, so oxygen ....

(a) gains 4 mol of electrons.
(b) gains 12 mol of electrons.
(c) loses 4 mol of electrons.
(d) loses 12 mol of electrons.

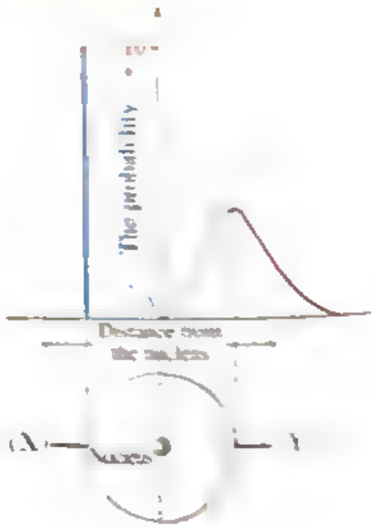
2 Which of the following choices represents the quantum numbers of the 19[th] electron in the atom of an element with atomic number 24 ?

Choices	n	l	m_l	m_s
(a)	4	0	0	$+\frac{1}{2}$
(b)	4	1	[illegible]	$-\frac{1}{2}$
(c)	3	2	[illegible]	[illegible]
(d)	3	2	[illegible]	[illegible]

3 Which of the following represents the electron configuration of sodium atom in the ground state that violates aufbau principle only ?

4 Which of the following describes each of (X) and (Y) in the opposite figure ?

Choices	(X)	(Y)
(a)	Orbital	Orbital
(b)	Orbit	Electron cloud
(c)	Orbit	Orbital
(d)	Orbit	Orbit



5. The following electron configurations belong to the atoms of known elements, except ....

(a) [Kr], $5s^2$, $4d^8$

(b) [Kr], $5s^2$, $4d^{10}$

(c) [Ar], $4s^1$, $3d^5$

(d) [Ar], $3d^{10}$

6. Based on the equation and the table :

$K_{(g)} + Cl_{(g)} \longrightarrow K^+_{(g)} + Cl^-_{(g)}$ $\quad \Delta H = ?$

	Ionization potential	Electron affinity
Potassium	+418 kJ/mol	–48 kJ/mol
Chlorine	+1255 kJ/mol	–349 kJ/mol

What is the value of ΔH of this process ?

(a) 1303 kJ/mol

(b) 1207 kJ/mol

(c) 767 kJ/mol

(d) 69 kJ/mol

7. Which of the following elements is located in the fourth period, where the value of (n) of its last electron is as high as possible and its (ℓ) value is the least ?

(a) Calcium.

(b) Manganese.

(c) Tin.

(d) Cesium.

8. What are the two ions forming Li_3N ?

(a) Li^+ , N^{3-} (b) Li_3^+ , N^- (c) Li^+ , N^- (d) Li^{3+} , N^{3-}

9. The following equations represent the probable reactions of the oxides of the two metals (M) and (X) with hydrochloric acid and sodium hydroxide.

- $MO_{(s)} + 2HCl_{(aq)} \longrightarrow MCl_{2(aq)} + H_2O_{(l)}$
- $XO_{2(g)} + 2NaOH_{(aq)} \longrightarrow Na_2XO_{3(aq)} + H_2O_{(l)}$

What are the probable symbols of (M) and (X) ?

Choices	Element (M)	Element (X)
(a)	Al	Cl
(b)	K	C
(c)	Mg	C
(d)	Na	Cl

10 Assisted by the values of electronegativity shown in the table.

What is the correct order of the strengths of these acids ?

Element	Electronegativity
H	2.1
O	3.5
Cl	3
Br	2.8
I	2.5

ⓐ HIO > HBrO > HClO

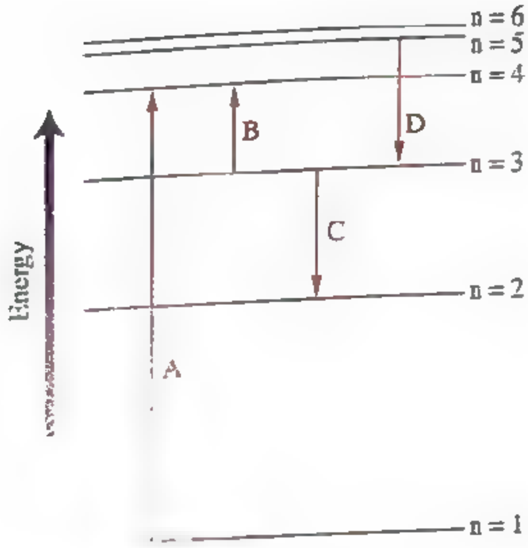
ⓑ HClO > HBrO > HIO

ⓒ HIO > HClO > HBrO

ⓓ HBrO > HClO > HIO

11 The opposite figure illustrates some travels of the electron of hydrogen atom between the different energy levels.

Which of these lines represents a visible spectral line of hydrogen atom ?



ⓐ A

ⓑ B

ⓒ C

ⓓ D

12 A transition metal ion X^{3+} its electron configuration is : [Ar] , $3d^4$

What is the atomic number of the element (X) ?

ⓐ 22

ⓑ 24

ⓒ 25

ⓓ 26

13 The chemical formula of the mineral talc (magnesium silicate) is : $Mg_3Si_4O_{10}(OH)_2$

What is the oxidation number of silicon in the mineral talc ?

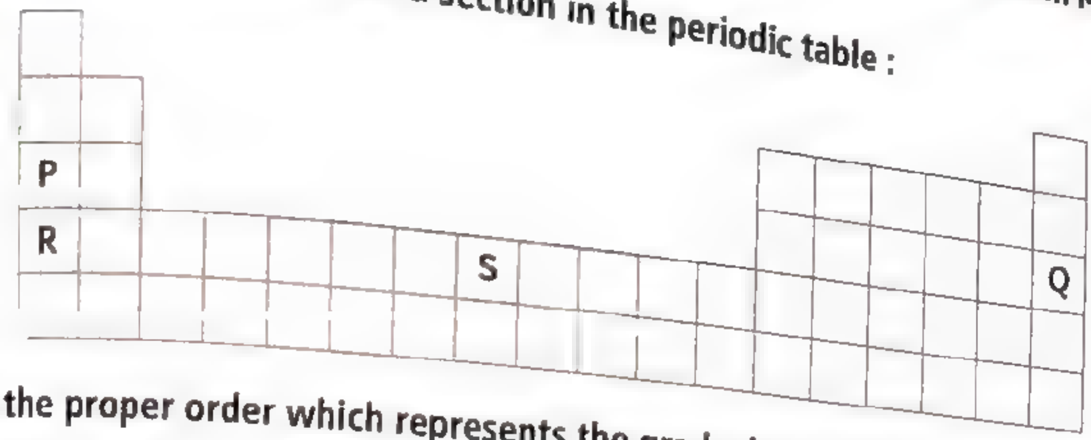
ⓐ −4

ⓑ −2

ⓒ +2

ⓓ +4

14 The following figure represents a section in the periodic table :



What is the proper order which represents the gradual ascending in the metallic property of the illustrated elements in this section ?

(a) Q < P < R < S
(b) Q < S < P < R
(c) S < P < R < Q
(d) Q < R < P < S

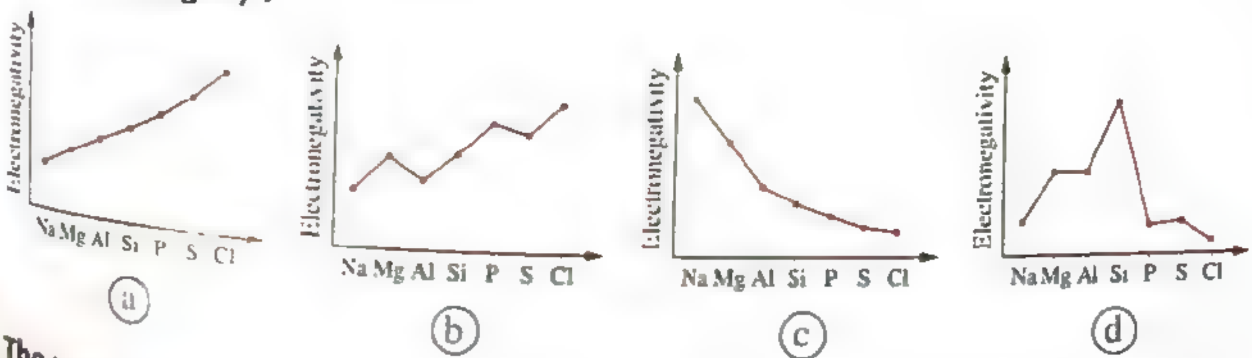
15 Which of the following equations represents the third ionization energy of bismuth Bi element ?

(a) $Bi^{+}_{(g)} \longrightarrow Bi^{3+}_{(g)} + e^{-}$
(b) $Bi^{2+}_{(s)} \longrightarrow Bi^{3+}_{(s)} + e^{-}$
(c) $Bi^{2+}_{(g)} + e^{-} \longrightarrow Bi^{3+}_{(g)}$
(d) $Bi^{2+}_{(g)} \longrightarrow Bi^{3+}_{(g)} + e^{-}$

16 What are the assumed quantum numbers of the electron which is added to gallium ($_{31}Ga$) atom when this electron is in its stable state ?

(a) $n = 4 , \ell = 1 , m_{\ell} = 0 , m_s = +\frac{1}{2}$
(b) $n = 3 , \ell = 2 , m_{\ell} = +2 , m_s = +\frac{1}{2}$
(c) $n = 4 , \ell = 0 , m_{\ell} = 0 , m_s = +\frac{1}{2}$
(d) $n = 3 , \ell = 0 , m_{\ell} = 0 , m_s = -\frac{1}{2}$

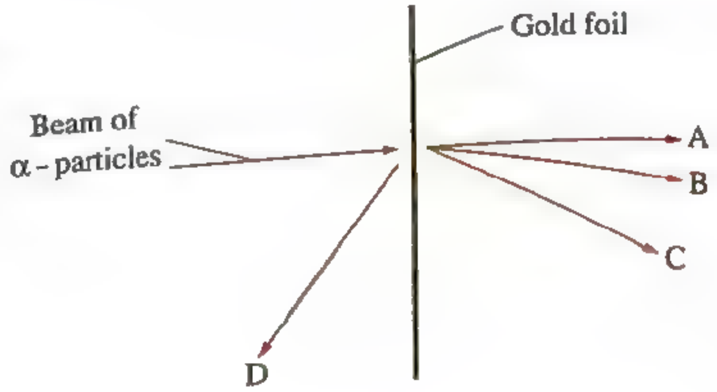
17 Which of the following graphical figures represents the graduation of the electronegativity property in the elements of the third period (excluding argon) ?



18 The most active nonmetal in the periodic table is the element which is ....

(a) the last in group zero.
(b) the first in group (7A).
(c) the last in group (2A).
(d) the first in group (5A).

19 When a beam of α-particles collides with a very thin gold foil (as represented in the figure), the final direction of most of these particles is ....



ⓐ A

ⓑ B

ⓒ C

ⓓ D

20 Which of the following electron configurations violates Pauli's principle ?

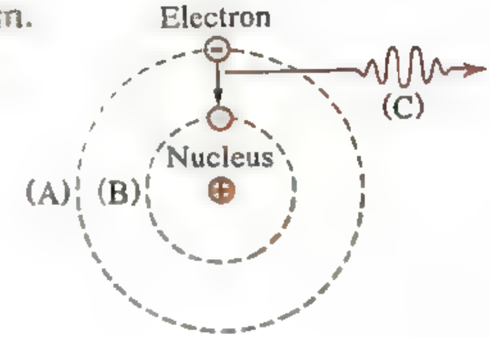
ⓐ [↑↓] [↑↓] [↑↓| |]

ⓑ [↑↓] [↑] [| |]

ⓒ [↑↓] [↑↑] [↑| |]

ⓓ [↑↓] [↑↓] [↑|↓|]

21 The opposite figure represents an excited hydrogen atom. What is the name of (C) which is produced from the movement of the electron from level (A) to level (B) ?



ⓐ Excited electron.

ⓑ Stable electron.

ⓒ Quantum.

ⓓ Visible spectrum.

22 What is the block of the elements which contains the highest number of the fifth period elements in the periodic table ?

....

....

1 mark

23 Calculate the number of the orbitals in the principal level (n = 5) which can be occupied by electrons in the actinides.

....

....

....

......
1 mark

24 A sample of an organic compound its mass is 10 g is composed of 92.3% C and 7.7% H
What is the percentage of carbon and hydrogen elements in a sample of the same compound its mass is 5 g ? **Explain.**
What is the name of the first scientist who suggested this answer ?

....

....

....

....

....

......
2 marks

25 Compare between perbromic acid $HBrO_4$ and hypobromous acid HBrO in terms of :

(1) Strength of the acid, **with explanation.**

....

....

....

....

....

(2) The oxidation number of bromine in each of them, **with illustration.**

....

....

....

....

......
2 marks

26 **The following table shows five successive elements which are located in one period in the periodic table :**

(A)	(B)	(C)	(D)	(E)
[Ne] , $3s^1$		....		

(1) **Write** the electronic configuration of the element (C) in its position in the previous table, **with writing** the quantum numbers of the last electron in element (D) atom.

....

....

(2) **Write** the symbolic equation which represents the reaction of one of the oxides of element (E) with water.

....

.... 2 marks

27 **Calcium element and strontium element [illegible] the second group in the periodic table :**

(1) **Why** is the ionic radius of strontium Sr^{2+} smaller than its atomic radius ?

....

....

....

....

(2) **What** is the number of the orbitals which are occupied by electrons in calcium atom in its ground state ?

....

....

.... 1 mark

Open Book Exam model 15

Answered

Rate your level

Superior	Remarkable	above average	Weak
from 30 marks to 27 marks	from 26 marks to 21 marks	from 20 marks to 15 marks	less than 15 marks

Choose the correct answer for the questions 1 : 21 .

21 marks

1 Which of the following statements about the groups of the periodic table is correct ?

ⓐ All groups contain metals and nonmetals.

ⓑ The elements in the same group have the same number of electrons.

ⓒ The chemical activity of the elements of group (1A) decreases by increasing the number of protons.

ⓓ H^+ is easier to be separated from the halogen acids with increasing the atomic number of the halogen.

2 All the following represent main transition elements, **except** ....

ⓐ $_{41}Z$

ⓑ $Y : [Ar] , 4s^2 , 3d^1$

ⓒ $W : [Xe] , 6s^2 , 4f^{14} , 5d^1$

ⓓ $_{110}X$

3 Chlorine element forms 4 oxyacids, which are :

$$(HClO / HClO_2 / HClO_4 / HClO_3)$$

What is the oxidation number of chlorine in the strongest acid ?

ⓐ +7 ⓑ +5

ⓒ +3 ⓓ +1

4 The opposite figure represents a section in the periodic table.

Which of the following represents the electronegativity for these elements ?

		$_{33}As$		
$_{49}In$	$_{50}Sn$	$_{51}Sb$	$_{52}Te$	$_{53}I$
		$_{83}Bi$		

Choices	The most electronegative element	The least electronegative element
ⓐ	As	Bi
ⓑ	I	In
ⓒ	I	Bi
ⓓ	Te	Sn

5 The following figures represent 4 atomic models :

(1) (2) (3) (4)

What is the correct historical order of these models ?

ⓐ (3) ⟶ (1) ⟶ (4) ⟶ (2)

ⓑ (2) ⟶ (1) ⟶ (4) ⟶ (3)

ⓒ (4) ⟶ (2) ⟶ (1) ⟶ (3)

ⓓ (2) ⟶ (4) ⟶ (1) ⟶ (3)

6 What are the quantum numbers of the eighth electron in oxygen atom ?

ⓐ $n = 2 , \ell = 1 , m_\ell = -1 , m_s = -\frac{1}{2}$

ⓑ $n = 2 , \ell = 1 , m_\ell = +1 , m_s = +\frac{1}{2}$

ⓒ $n = 2 , \ell = 1 , m_\ell = +1 , m_s = -\frac{1}{2}$

ⓓ $n = 2 , \ell = 0 , m_\ell = -1 , m_s = +\frac{1}{2}$

7 An element has the electron configuration : $[Xe], 4f^{14}, 5d^2, 6s^2$

What is the location of this element in the periodic table ?

ⓐ Sixth period, group (1).

ⓑ Sixth period, group (2).

ⓒ Sixth period, group (4).

ⓓ Sixth period, group (17).

8 Each of the following determines the type of the element according to its electron configuration, except ....

Choices	Electron configuration	Type of the element
ⓐ	$ns^{1:2} \rightarrow ns^2, np^6$	Representative
ⓑ	$1s^2$ or ns^2, np^6	Noble gas
ⓒ	$(n-1)d^{1:9}, ns^{1 \text{ or } 2}$	Main transition
ⓓ	$(n-2)f^{1:14}, (n-1)d^{1 \text{ or } 0}, ns^2$	Inner transition

9 The radius of Li^+ ion is close to that of ....

ⓐ Na^+ ion.

ⓑ Be^{2+} ion.

ⓒ Mg^{2+} ion.

ⓓ Al^{3+} ion.

10. Which of the following processes is accompanied by releasing energy ?

(a) $Sc_{(g)} \longrightarrow Sc^{+}_{(g)} + e^{-}$

(b) $F_{(g)} \longrightarrow F^{+}_{(g)} + e^{-}$

(c) $N_{(g)} - e^{-} \longrightarrow N^{-}_{(g)}$

(d) $Br_{(g)} + e^{-} \longrightarrow Br^{-}_{(g)}$

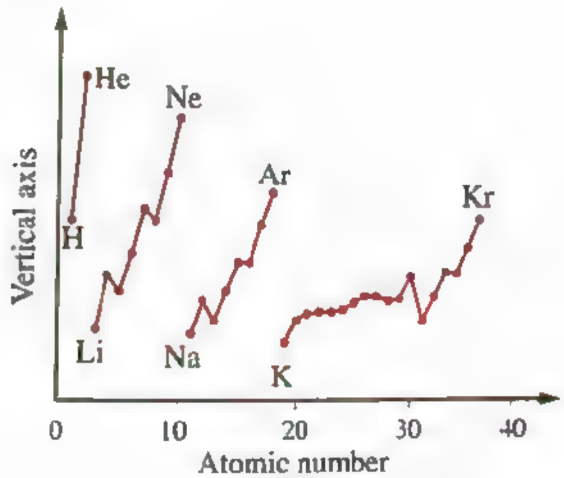
11. All the following oxides behave similarly during the chemical reactions, except ....

(a) MgO
(b) SnO
(c) ZnO
(d) PbO

12. Which of the following energy sublevels does not actually exist ?

(a) *2p*
(b) *3d*
(c) *5d*
(d) *3f*

13. What is the property which is represented by the vertical axis in the opposite graphical figure ?



(a) Atomic radius.
(b) Electron affinity.
(c) The first ionization potential.
(d) Electronegativity.

14. Germanium Ge is located in the same group of carbon and silicon in the periodic table. Which of the following choices represents the correct formulae of the different compounds of germanium ?

Choices	Germanium chloride	Germanium hydride	Germanium oxide
(a)	GeCl	GeH	GeO
(b)	GeCl	GeH_4	GeO_2
(c)	$GeCl_4$	GeH	GeO
(d)	$GeCl_4$	GeH_4	GeO_2

15 **What is the change which happens when a phosphorus atom $_{15}P$ is converted to a phosphide ion ?**

Choices	Number of unpaired electrons	Total number of electrons
(a)	Increases	Increases
(b)	Decreases	Increases
(c)	Increases	Does not change
(d)	Decreases	Does not change

16 **How does the strength of the elements as reducing agents change through the third period from Na to Ar ?**

(a) Decreases regularly.
(b) Increases regularly.
(c) Decreases then increases.
(d) Increases then decreases.

17 **What is the ascending graduation of the following elements in terms of the atomic radius ?**

(a) Cs < Na < Mg < Ba
(b) Mg < Na < Ba < Cs
(c) Mg < Ba < Na < Cs
(d) Ba < Mg < Na < Cs

18 **In which of the following elements the orbitals of 4d sublevel are occupied by electrons ?**

(a) $_{47}Ag$
(b) $_{56}Ba$
(c) $_{63}Eu$
(d) $_{77}Ir$

19 **Which of the following transition of the electron of hydrogen atom produces visible light emission ?**

(a) $(n = 1) \longrightarrow (n = 2)$.
(b) $(n = 5) \longrightarrow (n = 2)$.
(c) $(n = 3) \longrightarrow (n = 4)$.
(d) $(n = 3) \longrightarrow (n = 1)$.

20 **Which of the following is among the conclusions of Rutherford's experiment ?**

(a) Electrons revolve around the nucleus in definite orbitals.
(b) The mass and the positive charge of the atom are concentrated in its center.
(c) The atoms of the same element are similar in mass.
(d) The electron is a particle with mass and has the properties of waves.

21 Use the following redox reaction to answer the question :

$$MnO_4^- + 5Fe^{2+} + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

During the reaction, electrons transfer from ....

(a) $Fe^{3+} \longrightarrow Fe^{2+}$

(b) $Fe^{2+} \longrightarrow MnO_4^-$

(c) $MnO_4^- \longrightarrow Fe^{2+}$

(d) $MnO_4^- \longrightarrow Mn^{2+}$

22 The following table illustrates the ionization potentials (from the fifth to the eighth) of two elements (X) and (Y) in the third period in the periodic table :

Element	Ionization potentials (kJ/mol)			
	Fifth	Sixth	Seventh	Eighth
(X)	+7012	+8496	+27107	+31671
(Y)	+6542	+9362	+11018	+33606

(1) What is the number of the group of element (Y) ? Explain.

....

....

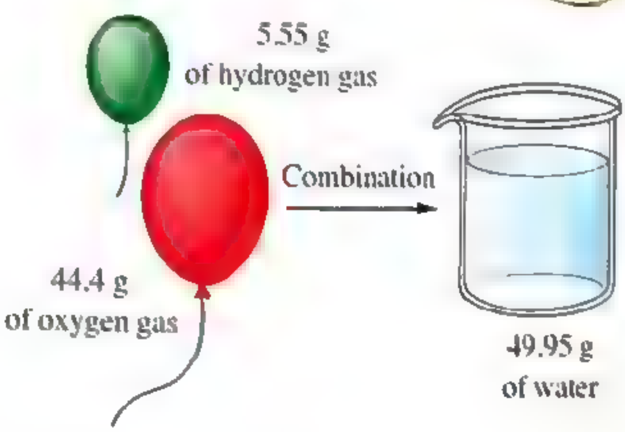
....

(2) Write the electronic configuration of the element (X) according to aufbau principle.

....

2 marks

23 The opposite figure represents one of the postulates of an atomic theory that you studied :



(1) What is the name of this theory ?

....

(2) State the postulate which is represented in the figure.

....

....

....

2 marks

24 In the two opposite figures :

(1) **Is there** changing in the path of the particles in both cases ?

....

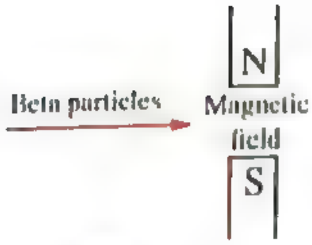


Figure (1)

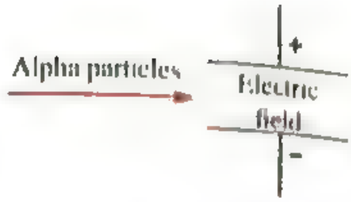


Figure (2)

(2) **Compare between** the path of each of alpha particles **and** beta particles when they both pass through the electric field which is illustrated in figure (2).

....

....

....

2 marks

25 The following figure represents a section in the periodic table :

Determine the symbol and the block .

....

....

1 mark

26 **Write the symbolic equation** which represents the electron affinity of selenium element Se

....

1 mark

27 **Illustrate the electronic configuration** of the two ions of zinc $_{30}Zn$ and copper $_{29}Cu$ elements in case of their similarity.

....

....

1 mark

EL-MOASSER

CHEMISTRY

GUIDE ANSWERS

2nd SEC. 2023

FIRST TERM

Answers of Chapter 1 lesson One

Ideas of answering the questions with the coloured numbers are clarified in the following pages :

Question number	1	2	3	4	5	6	7	8	9	10
Answer	c	c	a	d	c	c	d	c	d	d

Question number	11	12	13	14	15	16	17	18	19	20
Answer	d	d	c	d	d	c	d	d	c	d

Question number	21	22	23	24	25	26
Answer	c	c	b	c	a	a

Ideas of answering some of the multiple choice questions :

Question number	Idea of answering
2	Boyle's idea about the element is that it is a pure simple substance that can not be decomposed to simpler substances by any known chemical method. ∴ The correct choice is c
5	**Among Dalton's postulates are :** * The masses of the atoms of the same element are similar. ∴ The choice a is excluded.

* The masses of the atoms differ from one element to another.

∴ The choice (b) is excluded.

* The element atom is indivisible (can not undergo fission process).

∴ The correct choice is (c)

6 One of Dalton's postulates is that the compounds (just as water) are composed by the combination of the elements atoms (as oxygen and hydrogen in water) in simple numerical ratios.

∴ The correct choice is (c)

8

Element	C	H
Mass of the element in CH_4	12 g	$4 \times 1 = 4$ g
Mass ratio of the elements in CH_4	$\frac{12}{4} = 3$ g :	$\frac{4}{4} = 1$ g

∴ The correct choice is (c)

9

$$\begin{array}{lll} \text{Sulphur} + \text{Oxygen} & \longrightarrow & \text{Sulphur trioxide} \\ 32\text{ g} \quad\quad 48\text{ g} & & 80\text{ g} \\ 16\text{ g} & & ?\text{ g} \end{array}$$

Mass of the produced sulphur trioxide $= \frac{16 \times 80}{32} = 40$ g

$$\begin{array}{ccc} \text{Sulphur} & \xrightarrow{\text{reacts with}} & \text{Oxygen} \\ 32\text{ g} & & 48\text{ g} \\ 16\text{ g} & & ?\text{ g} \end{array}$$

Reacting mass of oxygen $= \frac{16 \times 48}{32} = 24$ g

Mass of oxygen remaining unreacting $= 100 - 24 = 76$ g

∴ The mass which remains in the container

= Sulphur trioxide mass + Remaining oxygen mass

$= 40 + 76 = 116$ g

∴ The correct choice is (d)

26 **In Rutherford's experiment :**

- A small fraction of α-particles were deflected from their path.
- A very small percentage of α-particles bounced back

Hence, the ratio between the number of alpha particles which are deviated (deflected) to that which bounce back is more than 1

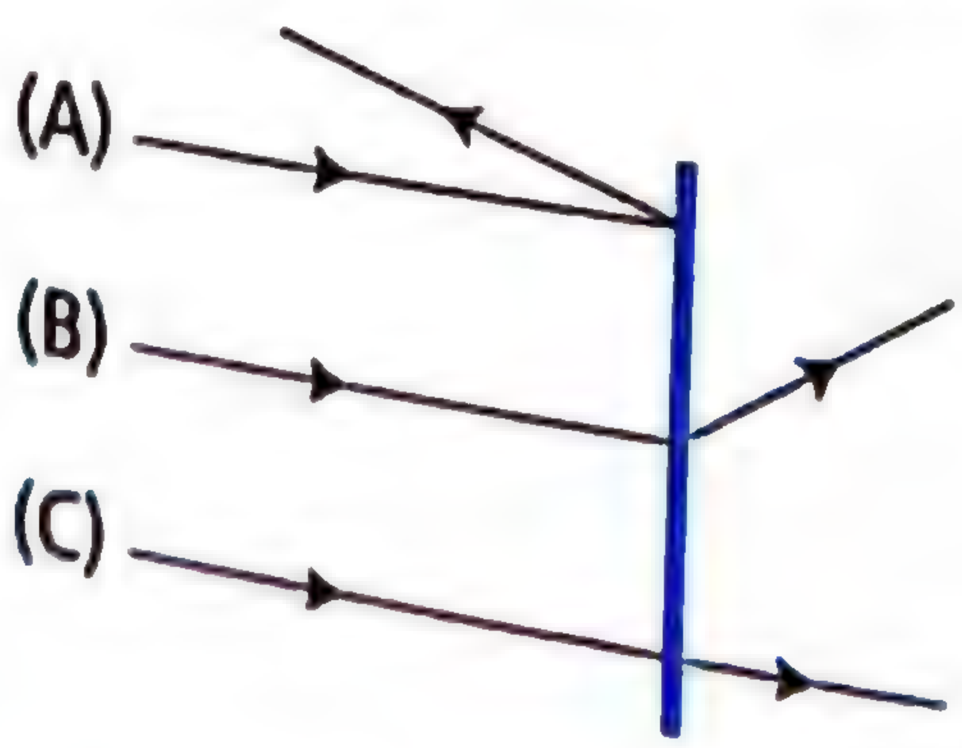
∴ The correct choice is (a)

Answers of essay questions

27 There is no effect / Because cathode rays do not differ in their behaviour or nature with the difference of the cathode material.

28 Particles (B) / As they pass in the spaces of the atom.

29 (1)



(2) To find out the ratio between the numbers of penetrating, reflected and the deflected alpha particles to identify the atomic structure on trial basis.

Answers of Chapter 1 lesson Two

Ideas of answering the questions with the coloured numbers are clarified in the following pages :

Question number	1	2	3	4	5	6	7	8	9	10
Answer	a	b	a	b	a	b	c	b	c	c

Question number	11	12	13	14	15	16	17	18	19	20
Answer	a	a	b	a	d	c	b	b	d	d

Question number	21	22	23	24	25	26	27	28	29	30
Answer	c	c	c	b	c	d	c	b	a	c

Question number	31	32	33	34	35	36
Answer	c	d	a	c	b	a

Ideas of answering some of the multiple choice questions :

Question number	Idea of answering
5	According to Bohr's model, the electron orbits the nucleus in a definite specific orbit. (i.e. there is one constant probability for the presence of the electron at a certain distance from the nucleus). ∴ The correct choice is (a)

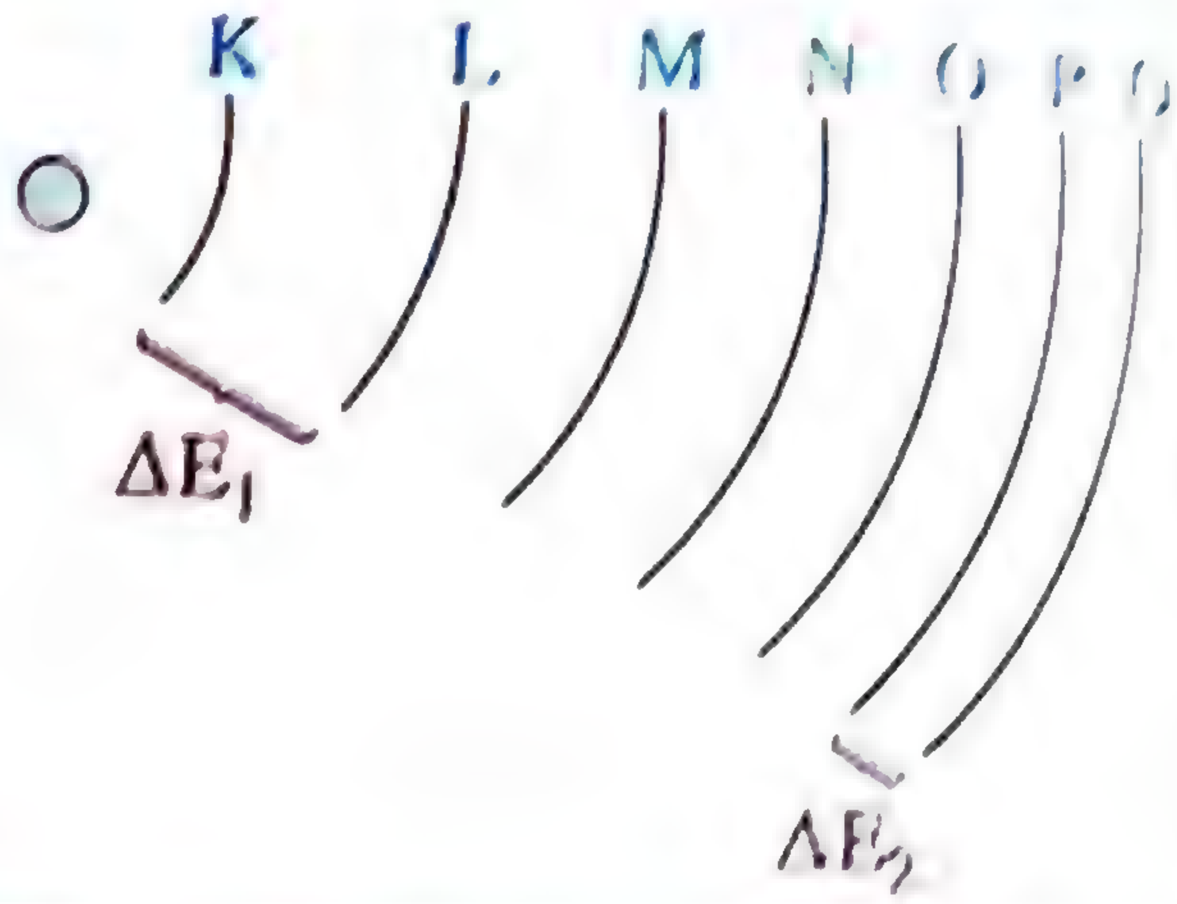
18 ∵ The wavelength of the photon is 486 nm

∴ The photon lies in the wavelength band of the visible spectrum (410 : 656 nm).

∵ The visible spectrum of hydrogen atom is produced by the transfer of the excited electron from energy levels higher than (n = 2) to the second energy level only.

∴ The correct choice is (b)

24 ∵ The difference in energy between each energy level and the level which follows it decreases by increasing the distance from the nucleus.



∴ $\Delta E_2 < \Delta E_1$

∴ The correct choice is (b)

25 To transfer from energy level L to K , the electron must lose a quantum of energy.

∴ The choices (b) and (d) are excluded.

∵ The difference in energy between the two levels (K and L) is higher than that between (L and M).

∴ The choice (a) is excluded.

∴ The correct choice is (c)

26 If the electron acquires a certain amount of energy, it can transfer to a higher energy level only when this amount of energy equals the difference in energy between these two levels (a quantum).

∵ The difference in energy between the level M and N (ΔE)

$= (-1 \times 10^{-19}) - (-5 \times 10^{-19}) = 4 \times 10^{-19}$ J

∵ The gained energy equals (3×10^{-19} J) which is lower than (4×10^{-19} J)

∴ The electron will remain in the energy level M

∴ The correct choice is (d)

Answers of essay questions

37 • Position (C) / Because the spaces between the energy levels are forbidden for the electrons.

• Position (X) / Because the electron revolves in the energy levels around the nucleus and not inside the nucleus.

38 The red light frequency / Because the wavelength of the red light is lower than that of infrared rays and the frequency is inversely proportional to the wavelength.

39 Because the frequency of the violet light is within the range of the frequencies of the visible spectrum, while the ultraviolet rays frequency is higher than that of the visible light.

40 As the wavelength of ultraviolet rays is less than 410 nm and that of infrared rays is higher than 656 nm, consequently they both are out of the visible spectrum.

41 The energy of the electron increases and it transfers from its stable energy level to a higher energy level (farther from the nucleus).

42 B / Because the visible spectrum is formed of the emission of quanta when the excited electron travels from the energy levels which are higher than (n = 2) to the energy level (n = 2) only.

43 (1) Bohr.

(2) Electron cloud.

Answers of Chapter 1 lesson Three

Ideas of answering the questions with the coloured numbers are clarified in the following pages :

Question number	1	2	3	4	5	6	7	8	9	10
Answer	c	c	c	a	a	d	c	b	c	a

Question number	11	12	13	14	15	16	17	18	19	20
Answer	d	c	c	b	c	b	c	c	b	d

Question number	21	22	23	24	25	26	27	28
Answer	d	c	b	a	c	d	a	c

Ideas of answering some of the multiple choice questions :

Question number	Idea of answering
8	$\because$ n = 4 , l = 1 $\therefore$ The sublevel is $4p$ $\because$ Each p sublevel consists of 3 orbitals, and each orbital becomes saturated by 2 electrons. $\therefore$ The maximum number of electrons = $3 \times 2 = 6e^-$ $\therefore$ The correct choice is (b)

9

$\because l = 3$

$\therefore$ The sublevel is f sublevel.

$\because$ The sublevel f consists of 7 orbitals, each of them becomes filled with 2 electrons, one of them spins clockwise (↑) and its $m_s = +\frac{1}{2}$, and the other spins anticlockwise (↓) and its $m_s = -\frac{1}{2}$

↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓

$\therefore$ The maximum number of electrons which have $(m_s = +\frac{1}{2}) = 7e^-$

$\therefore$ The correct choice is (c)

10

$\because$ The number of the orbitals of each sublevel can be estimated from the relation $(2l + 1)$.

$\because$ Each orbital becomes saturated by 2 electrons.

$\therefore$ The number of the electrons required to saturate each sublevel is estimated from the relation $2(2l + 1)$.

$\therefore$ The correct choice is (a)

14

$\because$ As the value of (l) increases, the number of the orbitals increases.

$\therefore$ The choices (a) and (d) are excluded.

$\because$ No. of the orbitals of the sublevel is estimated from the relation $(2l + 1)$.

$\therefore$ When $(l = 0)$, the number of the orbitals is 1 (not 0).

$\therefore$ The choice (c) is excluded.

$\therefore$ The correct choice is (b)

15

$\because$ Any orbital can not contain more than 2 electrons.

$\therefore$ The number of the electrons required to saturate any orbital is constant $(2e^-)$ no matter the (l) value is.

$\therefore$ The correct choice is (c)

18 ∵ The two figures are spherical symmetrical shapes around the nucleus.

∴ The two figures represent two *s* sublevels (with the same ($\ell = 0$), and the same distribution of electron density).

∴ The choices (a) and (b) are excluded.

∵ The two figures differ in size.

∴ The two sublevels differ in the principal quantum number (n).

∴ The correct choice is (c)

19 This table shows the number of electrons required to saturate each choice :

Choices	(a) One of $4f$ orbitals	(b) $3d$ sublevel	(c) Principal level (n = 2)	(d) One of $3d$ orbitals
No. of the electrons which saturate it	$2e^-$	$2 \times 5 = 10e^-$	$2(n)^2 = 2(2)^2 = 8e^-$	$2e^-$

∴ The correct choice is (b)

24 ∵ Electron (Y) and electron (X) have the same energy.

∴ Both of them have the same n and ℓ values.

∴ The choices (b) and (d) are excluded.

∵ The spinning motion of electron (Y) differs from that of electron (X).

∵ Electron (X) has m_s value $= -\frac{1}{2}$

∴ Electron (Y) has m_s value $= +\frac{1}{2}$

∴ The correct choice is (a)

25 When n = 3

∴ The possible values of (ℓ) are 0 , 1 and 2 only.

∴ The correct choice is (c)

Answers of essay questions

29 (1) **Values of (ℓ) :** 0, 1, 2, 3

(2) **Values of (m_ℓ) :** –3, –2, –1, 0, +1, +2, +3

30 Number of electrons in the principal level (n = 2) = $2n^2$ = 8 electrons.

Number of electrons in the sublevel *4d* = 2 × 5 = 10 electrons.

∴ The maximum number of electrons in *4d* sublevel is higher than that in the principal level (n = 2).

31 Number of orbitals = $n^2 = 2^2 = 4$ orbitals.

32 Zero.

33 0

34

Sublevel *f*	-3	-2	-1	0	+1	+2	+3
Sublevel *d*		-2	-1	0	+1	+2	
Sublevel *p*			-1	0	+1		
Sublevel *s*				0			

35 (1) Number of electrons = $2n^2 = 2 \times 3^2$ = 18 electrons.

(2) Number of electrons = Number of electrons of 2*s* sublevel = 2 electrons.

36 *2d, 3f, 1p*

37 (1) Because the possible values of (ℓ) in the principal level (n = 3) are 0, 1, 2 only.

(2) Because the possible values of (m_ℓ) in the sublevel (ℓ = 1) are –1, 0, +1 only.

(3) Because (m_ℓ) values are integer numbers only whether positive or negative, and the possible value of (m_ℓ) of the sublevel (ℓ = 0) is only 0

Ideas of answering the questions with the coloured numbers are clarified in the following pages :

Question number	1	2	3	4	5	6	7	8	9	10
Answer	d	b	a	c	b	b	c	d	b	a

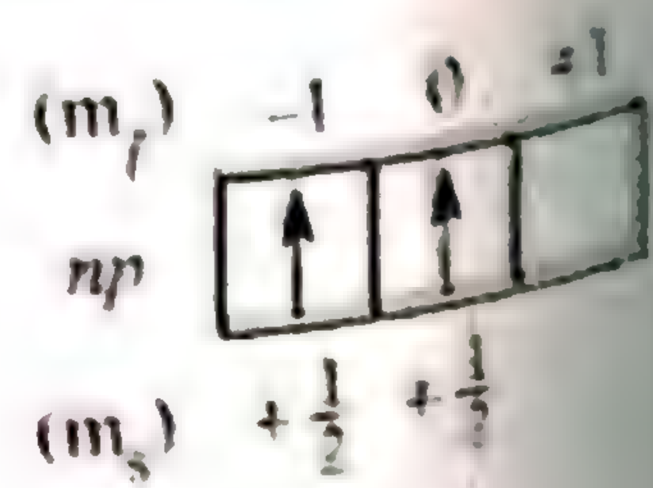
Question number	11	12	13	14	15	16	17	18	19	20
Answer	a	c	c	b	a	c	c	b	b	b

Question number	21	22	23	24	25	26	27	28	29	30
Answer	c	b	b	b	c	a	d	c	c	b

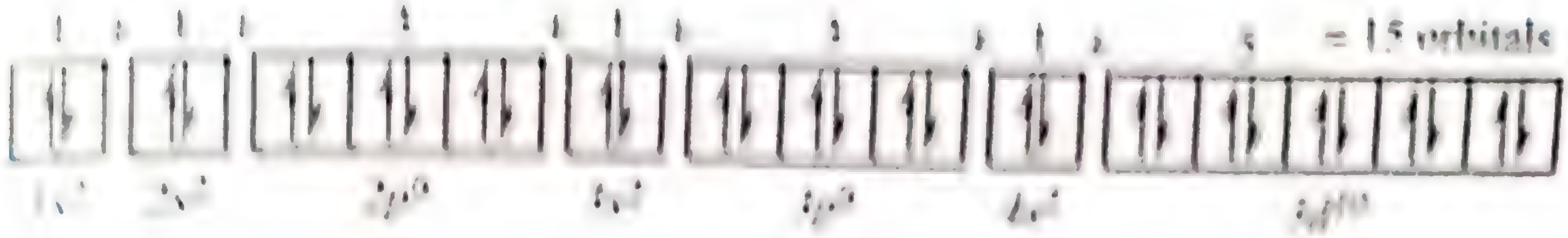
Question number	31	32	33	34	35	36	37	38
Answer	b	b	d	b	c	b	d	c

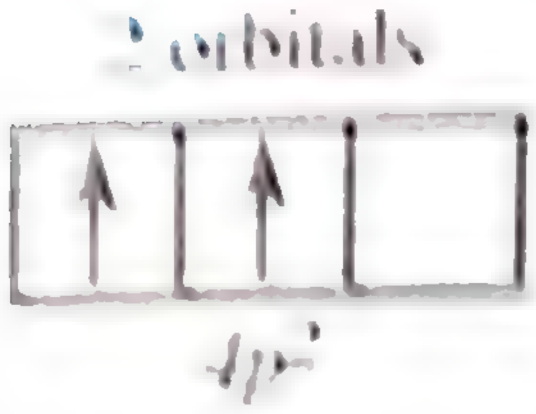
Ideas of answering some of the multiple choice questions :

Question number	Idea of answering
4	∵ The two electrons of the same sublevel which have the same m_s value must be located in two different orbitals. ∴ The two electrons differ in the magnetic quantum number m_l only. ∴ The correct choice is (c)



21





∴ Number of electrons of the last energy level

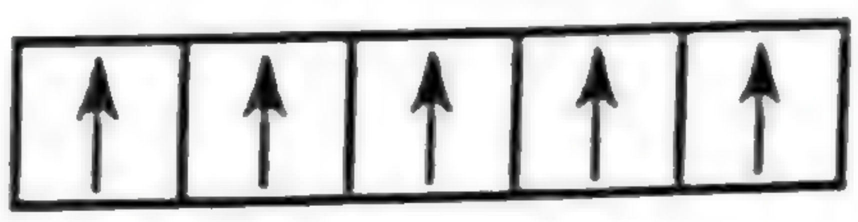
= The total number of electrons of the sublevels $4s$ and $4p$

$= 2 + 2 = 4$ electrons

∴ The correct choice is (c)

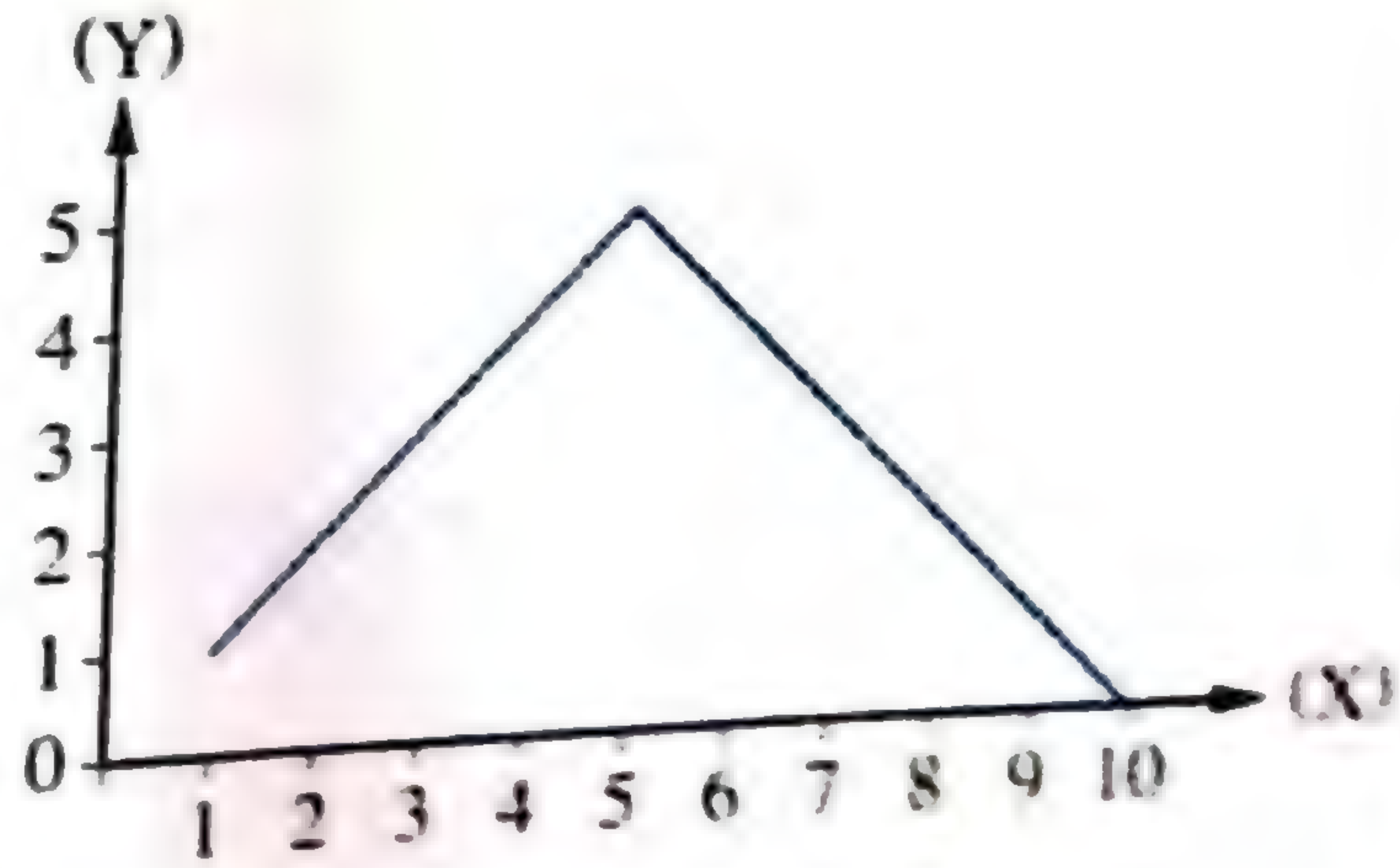
22 By increasing the number of the electrons in the sublevel $3d$,
the number of single electrons increases up to 5 single electrons.

half filled
$3d^5$

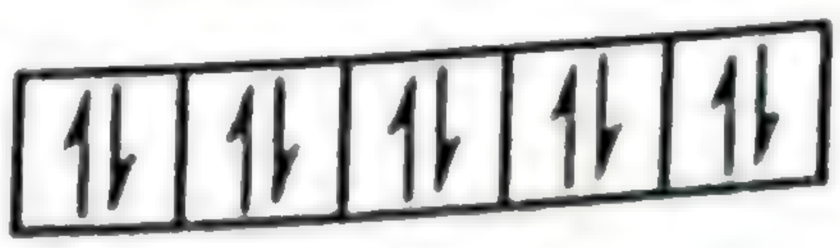


∴ The choices (a) and (c) are excluded.

∵ Pairing of electrons in the orbitals of $3d$ sublevel (according to Hund) starts after the half filling of these orbitals, which results in decreasing the number of the single (unpaired) electrons until it reaches zero.



completely filled
$3d^{10}$



∴ The correct choice is (b)

27 ∵ The sublevel which consists of 3 orbitals is p

∴ $\ell = 1$

∵ $n + \ell = 5$ ∴ $n = 4$

∴ The last sublevel in this element atom is $4p^1$

∴ The electron configuration of this element atom is :

$$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^1$$

∴ The atomic number of this element = 31

∴ The correct choice is (b)

---

28 ∵ The principal quantum number of the farthest electron from the nucleus $n = 4$

∴ The farthest electron is found in the 4^{th} principal energy level.

∵ No. of electrons in the level M is double that in level L ($16e^-$)

∴ The electronic configuration of the atom of this element is :

$$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^8$$

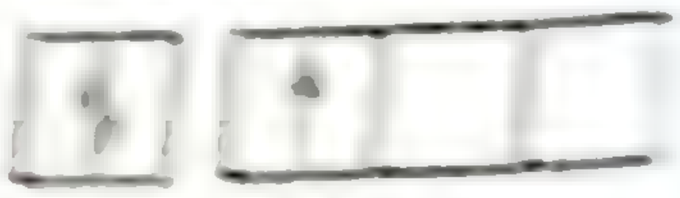
∴ The atomic number of element (X) = 28

∴ The correct choice is (c)

---

30 ∵ The last sublevel in X^{3+} ion is $2p^6$

∴ The electronic configuration of X atom ends with $3s^2, 3p^1$



$3s^2$ $3p^1$

∴ The number of half filled orbitals in X atom is 1

∴ The correct choice is (b)

---

31 Gallium $_{31}Ga$ atom in its excited state contains the same number of electrons found in its stable atom (31 electrons).

∴ The choices (a) and (d) are excluded.

∴ The electron configuration of the stable gallium atom is

$$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^1$$

It can be written like : 2 , 8 , 18 , 3

∴ This electronic configuration does not represent an excited atom.

∴ The choice (c) is excluded.

∴ The correct choice is (b)

35 $_{18}Ar : 1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6$

∵ The last sublevel in Ar atom $3p$ contains $6e^-$

∴ The choice (a) is excluded.

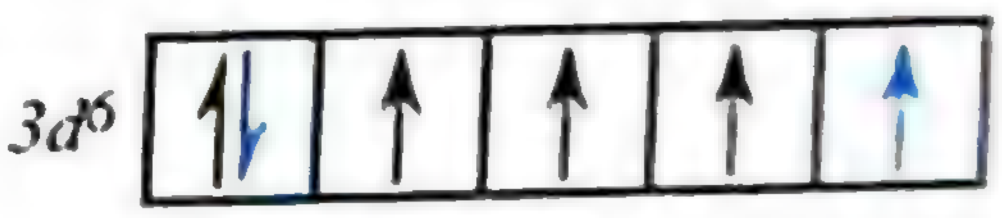
∵ The two electrons of the same orbital can not have the same spin quantum number.

∴ The choices (b) and (d) are excluded.

∴ The correct choice is (c)

37 $_{26}X : 1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2 , 3d^6$

∵ The last two electrons are found in $3d$ sublevel in 2 different orbitals.

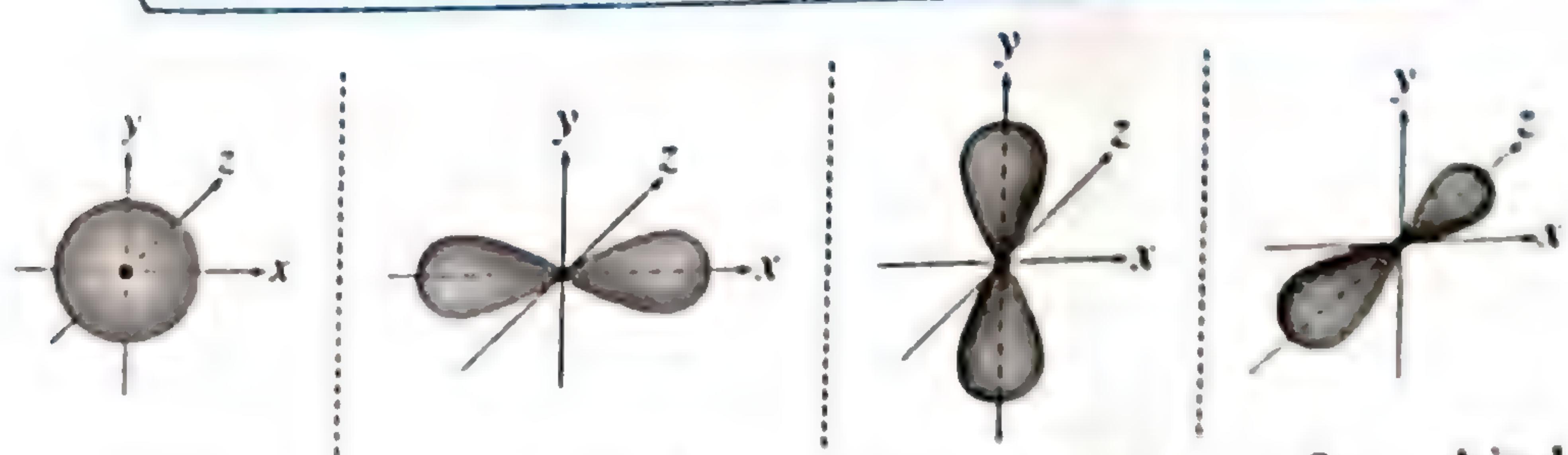


∴ The two electrons differ in the quantum numbers m_l and m_s

∴ The correct choice is (d)

Answers of essay questions

39



$2s$ orbital $2p_x$ orbital $2p_y$ orbital $2p_z$ orbital

40 **Any of these answers is correct :**

- $n = 3 \quad , \quad l = 1 \quad , \quad m_l = -1 \quad , \quad m_s = +\frac{1}{2}$
- $n = 3 \quad , \quad l = 1 \quad , \quad m_l = 0 \quad , \quad m_s = +\frac{1}{2}$
- $n = 3 \quad , \quad l = 1 \quad , \quad m_l = +1 \quad , \quad m_s = +\frac{1}{2}$
- $n = 3 \quad , \quad l = 1 \quad , \quad m_l = -1 \quad , \quad m_s = -\frac{1}{2}$
- $n = 3 \quad , \quad l = 1 \quad , \quad m_l = 0 \quad , \quad m_s = -\frac{1}{2}$
- $n = 3 \quad , \quad l = 1 \quad , \quad m_l = +1 \quad , \quad m_s = -\frac{1}{2}$

41 • **The similarities are :** The principal quantum number ($n = 2$) and the subsidiary quantum number ($\ell = 1$).

• **They may differ in :** The magnetic quantum number (m_ℓ) = -1 or 0 or $+1$ and the spin quantum number (m_s) = $+\frac{1}{2}$ or $-\frac{1}{2}$

42 $_{17}Cl$: $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$

• The last two electrons have the same (n) , (ℓ) , (m_ℓ) but they differ in (m_s).

Quantum numbers	(n)	(ℓ)	(m_ℓ)	(m_s)
First electron	3	1	+1	$+\frac{1}{2}$
Second electron	3	1	+1	$-\frac{1}{2}$

43 (1) • Pauli's principle is not applied due to the presence of two electrons with the same four quantum numbers in the first orbital of p sublevel.

• Hund's rule is applied where the pairing of the electrons did not happen before all orbitals were occupied with unpaired electrons first.

(2) • Pauli's principle is applied as there are no two electrons have the same four quantum numbers.

• Hund's rule is applied where the pairing did not happen before all orbitals were occupied with unpaired electrons first.

44 The last electron is found in the third orbital of $2p$ sublevel.

$\therefore$ The electronic configuration of the element is

$$1s^2 , 2s^2 , 2p^3$$

$\therefore$ The atomic number = 7

15 (1) $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2 , 3d^5$

$\therefore$ Maximum number of electrons = 25 electrons.

(2) $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2 , 3d^{10} , 4p^6 , 5s^2 , 4d^{10} , 5p^6 , 6s^2 , 4f^{14}$

$\therefore$ Maximum number of electrons = 70 electrons.

16 $\because$ **The electronic configuration :**

$_{22}Ti : 1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2 , 3d^2$

$\therefore$ The quantum numbers of the valence electrons, respectively, are :

① $n = 4$, $l = 0$, $m_l = 0$, $m_s = +\frac{1}{2}$

② $n = 4$, $l = 0$, $m_l = 0$, $m_s = -\frac{1}{2}$

③ $n = 3$, $l = 2$, $m_l = -2$, $m_s = +\frac{1}{2}$

④ $n = 3$, $l = 2$, $m_l = -1$, $m_s = +\frac{1}{2}$

17 (1) $\because$ The electronic configuration of the atom of the element (X) is :

$1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2 , 3d^{10} , 4p^4$

$\therefore$ The electronic configuration of the ion (X^{2-}) is

$1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2 , 3d^{10} , 4p^6$

(2) $4p^4$

$\uparrow\downarrow$	$\uparrow$	$\uparrow$

$n = 4$, $l = 1$, $m_l = -1$, $m_s = -\frac{1}{2}$

Answers of the exam model of chapter 1

Question number	1	2	3	4	5	6	7	8	9	10
Answer	d	d	b	c	d	b	d	a	c	b

Question number	11	12	13	14	15	16	17	18	19	20
Answer	c	a	c	b	b	d	c	d	c	a

Question number	21
Answer	b

22 (1) • **The electrons :** Are deflected towards the positive electrode / As they are negatively charged.

• **The protons :** Are deflected towards the negative electrode / As they are positively charged.

• **The neutrons :** Are not deflected / As they are neutral.

(2) The electrons deflection is stronger than that of the protons / Due to the negligible mass of the electron compared to that of the proton.

23

Orbital	(m_l)	(l)	(n)
$2p_x$	-1	1	2
$1s$	0	0	1
$4f$	$+3$	3	4
$4p_y$	0	1	4
$3d$	-2	2	3

24 (1) 1– Thomson's atomic model.

2– Rutherford's atomic model.

(2) The presence of negatively charged electrons inside the atom, enough for the atom to be electrically neutral

25 • The process (X).

• The quantum.

26 Figure (2) / Because the wavelength of the green light is lower than that of the red light.

27 • Figure (2) / $3p_y$

• Figure (3) / $2p_y$

Answers of Chapter 2 lesson One

Question number	1	2	3	4	5	6	7	8	9	10
Answer	c	d	c	d	b	b	b	d	c	d

Question number	11	12	13	14	15	16	17	18	19	20
Answer	a	c	c	c	a	b	a	a	a	b

Question number	21	22	23	24	25	26	27	28	29	30
Answer	d	b	c	c	c	d	a	c	d	a

Question number	31	32	33	34	35	36	37	38
Answer	d	b	a	d	a	a	a	c

Ideas of answering some of the multiple choice questions :

Question number	Idea of answering
1	∵ By increasing the atomic numbers of the elements down the same vertical group in the periodic table, the number of the principal energy levels which are occupied by electrons increases. ∴ The choices (b) and (d) are excluded.

∵ The increase in the atomic number on moving from one period to another in the same group is not regular (does not have a pattern).

∴ The choice (a) is excluded.

∴ The correct choice is (c)

23 The following table shows the electronic configurations of the atoms and the ions of the compounds mentioned in the choices and the number of the electrons in each of them :

Electronic configuration of the element atom	Electronic configuration of its ion	No. of electrons in the ion
$_{12}Mg : 1s^2, 2s^2, 2p^6, 3s^2$	$Mg^{2+} : 1s^2, 2s^2, 2p^6$	10
$_{17}Cl : 1s^2, 2s^2, 2p^6, 3s^2, 3p^5$	$Cl^- : 1s^2, 2s^2, 2p^6, 3s^2, 3p^6$	18
$_{11}Na : 1s^2, 2s^2, 2p^6, 3s^1$	$Na^+ : 1s^2, 2s^2, 2p^6$	10
$_8O : 1s^2, 2s^2, 2p^4$	$O^{2-} : 1s^2, 2s^2, 2p^6$	10
$_{16}S : 1s^2, 2s^2, 2p^6, 3s^2, 3p^4$	$S^{2-} : 1s^2, 2s^2, 2p^6, 3s^2, 3p^6$	18

∵ No. of Mg^{2+} electrons ≠ No. of Cl^- electrons.

∴ The choice (a) is excluded.

∵ No. of Na^+ electrons ≠ No. of Cl^- electrons.

∴ The choice (b) is excluded.

∵ No. of Mg^{2+} electrons = No. of O^{2-} electrons.

∴ The correct choice is (c)

36 ∵ The 4 quantum numbers of the last electron which has the highest energy in the atom of the transition element are :

$$n = 3 , \ell = 2 , m_\ell = +2 , m_s = +\frac{1}{2}$$

∴ The electron with the highest energy exist in the sublevel $3d^5$

∴ The electron configuration of this element atom is : [Ar], $4s^2$, $3d^5$

∵ The electron configuration of the last representative element in the same period of this transition element is : [Ar], $4s^2$, $3d^{10}$, $4p^5$, $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow}$

∴ The quantum numbers of the last electron in this representative element are :

$$n = 4 , \ell = 1 , m_\ell = 0 , m_s = -\frac{1}{2}$$

∴ The correct choice is (a)

Answers of essay questions

39 **It is obvious in the figure that the first period is not present, consequently :**

- Element (T) is located in the fourth period, group (2A), so its electronic configuration is [Ar], $4s^2$

  ∴ The atomic number of (T) = 18 + 2 = 20

- Element (U) is located in the fifth period, group 7 (7B), so its electronic configuration is [Kr], $5s^2$, $4d^5$

  ∴ The atomic number of (U) = 36 + 2 + 5 = 43

  The difference between their atomic numbers = 43 – 20 = 23

40 (1) Inner transition (an actinide).

(2) ∵ The electronic configuration of the element X ends with $7s^2$

∴ The electronic configuration of this element begins with the inert gas at the end of the sixth period which is radon $_{86}Rn$

∵ No. of the protons in the nucleus of its atom = Its atomic number

∴ No. of the protons in the nucleus of its atom = 86 + 2 + 1 + 4

= 93 protons

41

	Block	Type
(1)	d	Main transition
(2)	s	Representative

42

Element	Electronic configuration	Atomic number
(1)	[He] , $2s^2$, $2p^3$	7
(2)	[Ne] , $3s^2$, $3p^6$	18

43 (1) [He] , $2s^2$, $2p^1$

(2) • **Period :** Second. • **Group :** 13 (3A).

44 ∵ Element $_{23}B$ electronic configuration : [Ar], $4s^2$, $3d^3$

∴ It is located in the fourth period, group 5 (5B).

Consequently element A is located in the fifth period, group 4 (4B) , and its electronic configuration : [Kr], $5s^2$, $4d^2$

∴ The atomic number of A = 36 + 2 + 2 = 40

45 ∵ The metals of group (2A) tend to lose their valence electrons during the chemical reactions, forming M^{2+} ion.

∴ The general formula of their oxides : MO

46 ∵ The 6^{th} period begins with filling the principal level (n = 6) with electrons, and according to the Aufbau principle, the following sublevels are filled with electrons in the elements in this period : $6s^2$, $4f^{14}$, $5d^{10}$, $6p^6$

∴ Number of orbitals = 1 + 7 + 5 + 3 = 16 orbitals.

∴ The orbitals of these sublevels are occupied by 32 electrons, so that this period contains 32 elements.

Answers of Chapter 2 lesson Two

Ideas of answering the questions with the coloured numbers are clarified in the following pages :

Question number	1	2	3	4	5	6	7	8	9	10
Answer	d	a	d	d	c	b	c	c	a	a

Question number	11	12	13	14	15	16	17	18	19	20
Answer	b	b	c	a	c	b	a	b	a	a

Question number	21	22	23	24	25	26	27	28	29	30
Answer	c	a	d	b	a	d	a	c	d	b

Question number	31	32	33
Answer	b	b	d

Ideas of answering some of the multiple choice questions :

Question number	Idea of answering
12	∵ The atomic radius of sodium is larger than its ionic radius. ∴ The ratio between them is more than 1 ∴ The choices (a) and (d) are excluded. ∵ The ratio between them in (c) approaches 1 ∴ The choice (c) is excluded. ∴ The correct choice is (b)

18

The 4 quantum numbers show that the last electron in this element atom exists in the sublevel $4f$, consequently, element (X) is located in the 6^{th} period.

n	l	m_l	m_s
4	3	0	$+\frac{1}{2}$

∵ Element (Y) is located in the same period of (X) and has the largest atomic size.

∴ Element (Y) is located in the 6^{th} period, group (1A).

∵ The electronic configuration of element (Y) which is : $[Xe], 6s^1$ shows that its atomic number is 55

∴ The correct choice is (c)

15

$$X_{(g)} + \text{Energy} \longrightarrow X^+ + e^-$$

∵ This equation represents the first ionization potential (gained energy) of an element which must be higher than the difference in energy between the last energy level (the valence shell) and the level Q which is the last energy level in the heaviest known atom, as this ionization potential (absorbed energy) is required to liberate the electron which is most loosely bound to the nucleus (the valence electron).

∴ The correct choice is (c)

20

∵ The atomic number of element (X) is less than both atomic numbers of (Y) and (Z).

∴ The choices (b) and (c) are excluded.

∵ The electron configurations of carbon and nitrogen are :

$_6C : 1s^2, 2s^2, 2p^2$

$_7N : 1s^2, 2s^2, 2p^3$

∴ The atom of $_7N$ is more stable than that of $_6C$, as its $2p$ sublevel is half filled with electrons, so the loss of an electron from this half filled sublevel decreases its stability, hence its first ionization potential is higher.

∴ The correct choice is (a)

21 $_{13}Al : [Ne] . 3s^2 . 3p^1$

∵ The valence shell of aluminum contains 3 electrons.

∴ The fourth ionization potential of aluminum is much higher than the third.

∴ The correct choice is (c)

24 ∵ The third ionization potential of element X is much higher than the second.

∴ X is a divalent metal.

∵ Chlorine is a monovalent nonmetal.

∴ The formula of the compound produced from the combination of X with chlorine is XCl_2

∴ The correct choice is (b)

26 ∵ By increasing the atomic number, the electron affinity increases in the same period.

∴ The choices (b) and (c) are excluded.

∵ The increase in the electron affinity in the same period is not regular.

∴ The choice (a) is excluded.

∴ The correct choice is (d)

34 The atomic radius of oxygen = $\frac{\text{Bond length in } O_2 \text{ molecule}}{2}$

$\therefore r(O) = \frac{1.32}{2} = 0.66\,\mathring{A}$

The atomic radius of hydrogen =

(O – H) bond length – The atomic radius of oxygen

$\therefore r(H) = 0.96 - 0.66 = 0.3\,\mathring{A}$

35 The atomic radius of hydrogen =
(H – Cl) bond length – The atomic radius of chlorine
$\therefore r(H) = 1.29 - 0.99 = 0.3\,\text{Å}$
$\therefore 2r(H_2) = 2 \times 0.3 = 0.6\,\text{Å}$
The atomic radius of nitrogen =
(N – H) bond length – The atomic radius of hydrogen
$\therefore r(N) = 1 - 0.3 = 0.7\,\text{Å}$
$\therefore 2r(N_2) = 2 \times 0.7 = 1.4\,\text{Å}$
$\therefore$ The bond length of nitrogen molecule (1.4 Å) is longer than that of hydrogen molecule (0.6 Å).

36 (1) The bond length in the formula unit of NaCl = $r(Na^+) + r(Cl^-)$
$= 0.98 + 1.81 = 2.79\,\text{Å}$
as it is an ionic compound.
(2) The bond length in HCl molecule = $r(H) + r(Cl)$
$= 0.3 + 0.99 = 1.29\,\text{Å}$
as it is a covalent compound.

37 (1) $_{20}Ca > {}_{12}Mg > {}_{17}Cl$ / As the radius increases in the same group by increasing the atomic number and decreases in the same period by increasing the atomic number.
(2) $I_2 > Br_2 > Cl_2 > F_2$ / As the radius (and consequently the bond length) increase in the same group by increasing the atomic number.

38 The statements (2) and (3).

39 (1) Because the increase in the number of the negative electrons more than the number of the positive protons in sulphide anion increases the repulsion forces between the electrons, leading to increasing the size of the anion.
(2) Because the number of positive protons in Ca^{2+} is higher than the number of positive protons in S^{2-}, consequently the effective nuclear charge in Ca^{2+} is higher, so this causes the radius to decrease.

40 ∵ Its 6^{th} ionization potential is very high compared to the 5^{th} ionization potential

∴ Removing the 6^{th} electron requires breaking a completely filled level, consequently this element has 5 electrons in its valence shell.

∵ It is located in the third period.

∴ **Its electronic configuration is :** $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^3$

41 (1) Second ionization potential.

(2) Y^+ is larger in radius / As the ionic radius of the positive ion decreases by increasing its positive charge.

42 $Ti^{2+}_{(g)}$ + Energy $\longrightarrow$ $Ti^{3+}_{(g)}$ + e^- , $\Delta H = (+)$

43 First ionization potential of sodium $Na_{(g)}$ and the electron affinity of chlorine $Cl_{(g)}$

44 Because the element M atom may lose an electron forming M^+ ion, and it may lose second electron forming M^{2+}, and so on...
While the electron affinity is a property of a single gaseous atom only, which forms a negative ion when it gains an electron.

45 (1) • Number of electrons in chromium ion Cr^{2+} in CrO = 22 electrons.
• Number of electrons in chromium ion Cr^{3+} in Cr_2O_3 = 21 electrons.

(2) The bond length in the formula unit of chromium (II) oxide is longer / As its ionic radius increases by decreasing the positive charge, hence the bond length increases.

46 **Figure (1) :** $_9F$ **Figure (2) :** $_{35}Br$ **Figure (3) :** Br^-

As the ionic radius of the negative ion is larger than its atomic radius, and the radius increases in the same group by increasing the atomic number.

47 (1) B (2) D (3) I (4),(5) K (6) I , Y

Answers of Chapter 2 lesson Three

Ideas of answering the questions with the coloured numbers are clarified in the following pages :

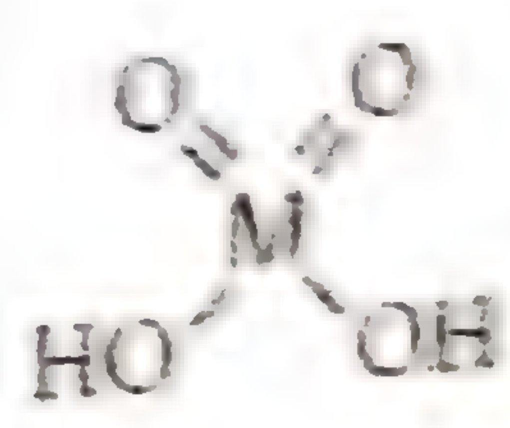
Question number	1	2	3	4	5	6	7	8	9	10
Answer	c	d	a	d	b	c	a	c	d	d

Question number	11	12	13	14	15	16	17	18	19	20
Answer	c	d	a	d	b	a	a	d	a	b

Question number	21	22	23	24
Answer	c	d	d	a

Ideas of answering some of the multiple choice questions :

Question number	Idea of answering
2	It is obvious in the graphical figure that the ionization potentials of the two elements (X) and (Z) are relatively high. ∴ The choices (a) and (c) are excluded. ∵ The electron configurations of the atoms of the two elements (Y) and (W) are : $_3Y$: [He], $2s^1$ $_{11}W$: [Ne], $3s^1$

	This shows that element (W) follows element (Y) directly in their group (1A). ∴ The atom of element (W) loses its valence electron easier than the atom of element (Y). ∴ The correct choice is (d)
11	∵ The mixture of the two oxides dissolves in water forming a neutral solution. ∴ One of these oxides is acidic and the other is basic. ∵ Na_2O and MgO are basic oxides, while SO_3 and P_4O_{10} are acidic oxides. ∴ The choices (b) and (d) are excluded. ∵ The two oxides are of elements of the third period, while nitrogen lies in the second period. ∴ The choice (a) is excluded. ∴ The correct choice is (c)
21	From the hydroxy formula of the oxygenated acid which is shown in the opposite figure, it is concluded that this element shares 6 electrons in the formation of the bonds.  ∴ The probable electronic configuration of the last principal level in M atom is : ns^2 , np^4 ∴ The correct choice is (c)

23 The following table shows the oxygenated acid of each anion and its hydroxy formula :

Anion	SO_4^{2-}	ClO_2^-	ClO_3^-	ClO_4^-
Oxygenated acid	H_2SO_4	$HClO_2$	$HClO_3$	$HClO_4$
Hydroxy formula	$SO_2(OH)_2$	$ClO(OH)$	$ClO_2(OH)$	$ClO_3(OH)$

∵ The strength of the oxygenated acid increases by increasing oxygen atoms nonbinded to hydrogen in it.

∴ $HClO_4$ is the strongest oxygenated acid.

∴ The correct choice is (d)

24 ∵ (O – H) bond is stronger than (O – M) bond.

∴ The compound is being ionized as a base.

∴ M^+ ion is an ion of a metal of s–block.

∴ The correct choice is (a)

Answers of essay questions

25 (1) • **Element (X) : [Ne] , $3s^2$, $3p^5$**

• **Element (Y) : [Ne] , $3s^1$**

(2) Element (Y) / As it is a metal, which tends to lose the electron of its valence shell forming a positive ion with the same electronic configuration of the nearest noble gas that precedes it in the periodic table.

26 • (X / Mg) , (Y / K) , (Z / Al).

• Ordering according to the metallic property : K > Mg > Al

27 (1) $Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O$

(2) $Al_2O_3 + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 3H_2O$

28 As (O – H) bond is stronger than (Cs – O) bond in cesium hydroxide, while (Cl = O) bond is stronger than (O – H) bond in $ClO_3(OH)$.

29 (1) 3 atoms.

(2) As when it dissolves in water, it yields a basic solution.

Answers of Chapter 2 Lesson Four

Ideas of answering the questions with the coloured numbers are clarified in the following pages :

Question number	1	2	3	4	5	6	7	8	9	10
Answer	b	d	c	b	b	d	c	b	a	a

Question number	11	12	13	14	15	16	17	18	19	20
Answer	c	d	c	d	d	c	b	c	b	b

Question number	21	22	23	24	25	26	27	28
Answer	c	c	d	a	b	d	d	d

Ideas of answering some of the multiple choice questions :

Question number	Idea of answering
25	$4H_2SO_4 + 3H_2S + K_2Cr_2O_7 \longrightarrow 7H_2O + K_2SO_4 + 3S + Cr_2(SO_4)_3$ ∵ Obviously, the oxidation number of sulphur in sulphate group (SO_4^{2-}) does not change in any of its compounds. ∴ It does not participate in the oxidation–reduction process. ∴ Sulphur of H_2S is exposed to an oxidation process. ∵ $3H_2S \longrightarrow 3S$ $S = -2 \qquad S = 0$ ∴ No. of sulphur atoms which are exposed to oxidation is 3 ∴ The correct choice is b

40 The oxidation number of Y in Y_2Z :

$2Y + (+4) = 0$ $\therefore Y = -2$

The oxidation number of each of Na and H can not be -2

The choices (a) and (b) are excluded.

Oxidation number of Cl can be +4 in some of its compounds.

Z is Cl and Y is O

The correct choice is (d)

41 The atomic groups ClO_3 , MnO_4 and ClO_4 are monovalent.

Oxidation number of Cl in ClO_3	$-1 = Cl - 6 \Longrightarrow \therefore Cl = +5$
Oxidation number of Mn in MnO_4	$-1 = Mn - 8 \Longrightarrow \therefore Mn = +7$
Oxidation number of Cl in ClO_4	$-1 = Cl - 8 \Longrightarrow \therefore Cl = +7$
Oxidation number of Mn in MnO_2	$0 = Mn - 4 \Longrightarrow \therefore Mn = +4$

$\overset{+5}{Cl}O_3 \longrightarrow \overset{+7}{Cl}O_4 + 2e$ (1)

$\overset{+7}{Mn}O_4 + 3e \longrightarrow \overset{+4}{Mn}O_2$ (2)

To balance the number of each of the lost and the gained electrons in the oxidation reduction reaction, this requires to multiply :

Equation (1) × 3

Equation (2) × 2

$\therefore$ W = 3 and Y = 2

$\therefore$ The correct choice is (d)

Answers of essay questions

29 $\overset{-2}{(BrO)^-} \longrightarrow \overset{-2}{(BrO_3)^{2-}}$

$Br + (-2) = -1$ $\qquad$ $Br + (-2 \times 3) = -2$

$Br = +1$ $\qquad$ $Br = +4$

oxidation

Bromine has been oxidized / As its oxidation number increased from +1 to +4

30 Sodium zincate $\overset{+1}{Na_2}Zn\overset{-2}{O_2}$

$(+1 \times 2) + Zn + (-2 \times 2) = 0$

$\therefore Zn = +4 - 2 = +2$

31 $H_2\overset{-2}{S} \xrightarrow{\text{oxidation}} \overset{0}{S}$

$\overset{+4}{S}O_2 \xrightarrow{\text{reduction}} \overset{0}{S}$

- The oxidizing agent is SO_2
- The reducing agent is H_2S

32 (1) Element (D) / Electronic configuration : $[Ar]$, $4s^2$, $3d^5$

Oxidation numbers : (+2 , +3 , +4 , +5 , +6 , +7).

(2) Element (A).

33 **(1) Anion :** $(NO_3)^-$

$N + (-2 \times 3) = -1$

$N = +5$

(2) Cation : $(NH_4)^+$

$N + (+1 \times 4) = +1$

$N = -3$

34 (1) 1. (W). $\qquad$ 2. (X).

(2) -2

Answers of the exam model of chapter 2

Question number	1	2	3	4	5	6	7	8	9	10
Answer	a	a	d	c	d	a	b	d	d	a

Question number	11	12	13	14	15	16	17	18	19	20
Answer	b	d	b	b	c	b	b	a	b	c

Question number	21
Answer	d

22 Element (Y) / Because when its atom returns to the stable state, the electron moves from a higher energy level (n = 6) to a lower energy level (n = 3).

23 (1) p-block.

(2) Element (A) : [He], $2s^2$, $2p^6$

Element (B) : [Ar], $4s^2$, $3d^{10}$, $4p^3$

24 (1) • The hydroxy formula of HIO is I(OH)

• The hydroxy formula of $HClO_3$ is $ClO_2(OH)$

∴ $HClO_3$ is stronger / Because the strength of the oxygenated acid increases with increasing the number of oxygen atoms nonbinded to hydrogen in this acid.

(2) • $\overset{+1}{H}I\overset{-2}{O}$: +1 + I − 2 = 0 , I = +1

• $\overset{+1}{H}Cl\overset{-2}{O_3}$: +1 + Cl + (−2 × 3) = 0 , Cl = +5

25 $_{24}Cr$: [Ar], $4s^1$, $3d^5$

$_{25}Mn$: [Ar], $4s^2$, $3d^5$

26 It means that the distance between the centers of the nuclei of each of Na^+ and Cl^- ions which are combined in the formula unit of NaCl crystal equals 2.79 Å

27 $_{10}Ne$: [He], $2s^2$, $2p^6$

$_{11}Na$: [Ne], $3s^1$

• Due to the stability of the electronic system of neon and the difficulty of the separation of an electron from a completely filled energy level.

Answers of the questions of 2021 exam

Question number	1	2	3	4	5	6	7	8	9	10
Answer	d	d	a	c	d	d	c	c	b	a

Question number	11	12	13	14	15	16	17	18	19	20
Answer	b	d	c	a	d	b	a	c	d	a

Question number	21
Answer	b

Answers of the questions of 2020 exam

Question number	1	2	3	4	5	6	7	8	9	10
Answer	d	a	d	b	c	d	a	b	d	d

Question number	11	12	13	14	15	16	17	18	19	20
Answer	a	b	c	b	c	c	c	d	a	b

Question number	21	22	23	24	25	26	27	28	29	30
Answer	a	a	a	d	d	d	a	c	b	d

Question number	31	32	33	34	35	36	37	38	39
Answer	d	a	c	a	a	b	d	b	a

Answers of the guiding model

Question number	1	2	3	4	5	6	7	8	9	10
Answer	d	b	a	d	c	b	a	a	b	a

Question number	11	12
Answer	c	c

Answers of exam model 1

Question number	1	2	3	4	5	6	7	8	9	10
Answer	b	d	d	a	c	c	b	a	b	a

Question number	11	12	13	14	15	16	17	18	19	20
Answer	c	c	d	d	a	c	b	d	c	a

Question number	21
Answer	a

22 Oxidation number of the element = +2

Because the electronic configuration of the element ends with the sublevel ns^2, so its atom tends to lose two electrons to give a positive ion that carries two positive charges.

23 Electron (X) / As the sum of $(n + l)$ of $4f$ sublevel $(4 + 3 = 7)$ of the electron (X) is higher than the sum of $(n + l)$ of $6s$ sublevel $(6 + 0 = 6)$ of the electron (Y).

24 (1) ∵ Number of elements of s-block = 12 elements

Number of elements of p-block = 36 elements.

∴ The difference between them = 36 − 12 = 24 elements

(2) Elements of f-block

25 Figure (1).

26 $_{23}V : 1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^6 , 4s^2 , 3d^3$

Number of completely filled orbitals = 1 + 1 + 3 + 1 + 3 + 1 = 10 orbitals.

Number of partially occupied orbitals = 3 orbitals.

27 $(n = 4) , (l = 1) , (m_l = -1) , (m_s = +\frac{1}{2})$.

Answers of exam model 2

Question number	1	2	3	4	5	6	7	8	9	10
Answer	a	c	c	b	d	b	c	a	a	b

Question number	11	12	13	14	15	16	17	18	19	20
Answer	a	c	b	a	b	b	b	a	c	d

Question number	21
Answer	c

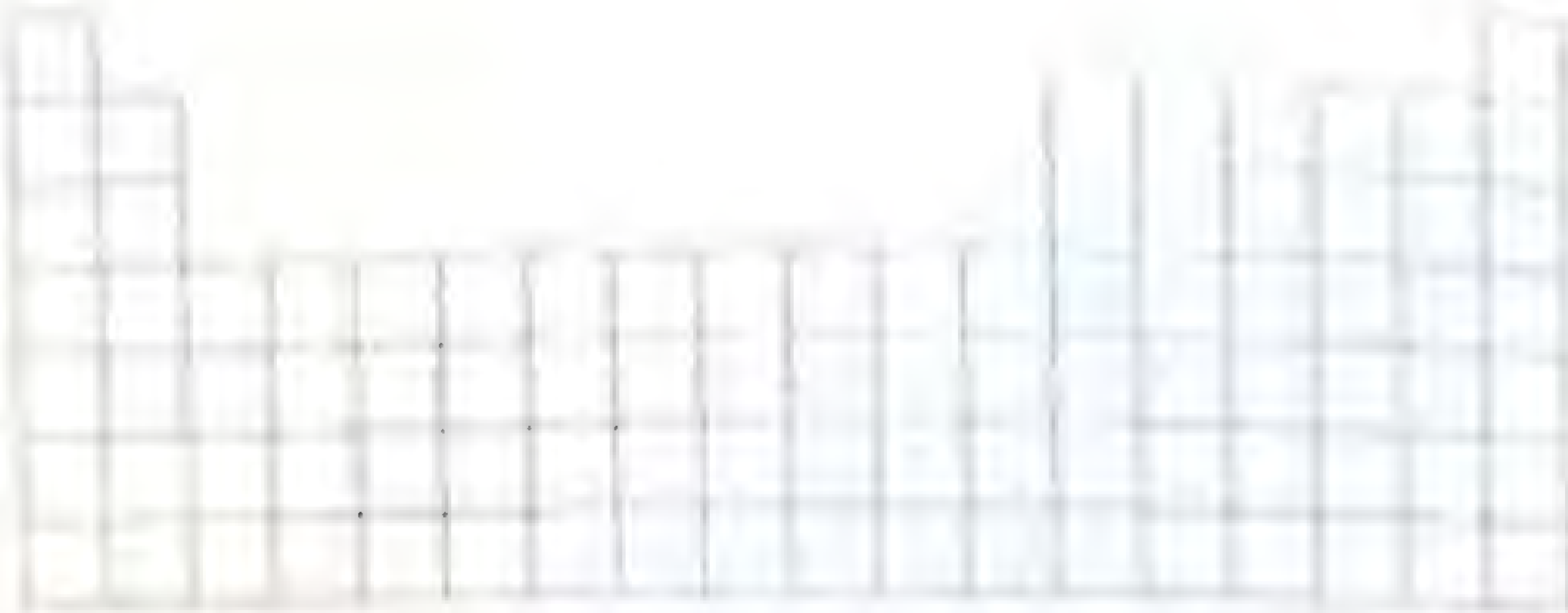
22 $_{21}Sc : [Ar] , 4s^2 , 3d^1$

The second set / As it represents the electron of 4s sublevel that occupies the 4^{th} energy level which is the farthest from the nucleus.

23 (1) ∵ Number of representative elements = 43 elements.

Number of main transition elements = 40 elements.

∴ The difference between them = 43 – 40 = 3 elements.

(2) 

24 (1) (C) (2) (D)

25 $NaClO_3$ / Where the oxidation number of chlorine = +5

26 $Al_2O_{3(s)} + 3H_2SO_{4(aq)} \longrightarrow Al_2(SO_4)_{3(aq)} + 3H_2O_{(l)}$

27 HClO / n = Zero

Answers of exam model 3

Question number	1	2	3	4	5	6	7	8	9	10
Answer	b	c	d	c	a	c	d	b	a	b

Question number	11	12	13	14	15	16	17	18	19	20
Answer	c	a	d	d	a	a	b	c	b	d

Question number	21
Answer	b

∵ The electron configuration of element X ends with the sublevel $4s^1$

∴ X is potassium $_{19}K$

∴ KOH is ionized as a base, as its atomic size is large, and its ion carries one positive charge, so its attraction to oxygen ion O^{2-} decreases, and (O – H) bond becomes stronger than (K – O) bond, and hence negative hydroxide ion is formed.

$$KOH \longrightarrow K^+ + OH^-$$

23 The electrons are deflected towards the positive electrode / As they are negatively charged.

24 $_{24}Cr$: [Ar] , $4s^1$, $3d^5$ $_{25}Mn$: [Ar] , $4s^2$, $3d^5$

Yes / Due to the similarity between chromium and manganese, where the atom is more stable when $3d$ sublevel is half filled with electrons.

25 (1) • (X): MgO • (Y): H_2SO_4

(2) $MgO_{(s)} + H_2SO_{4(aq)} \longrightarrow MgSO_{4(aq)} + H_2O_{(l)}$

Compound (X) Compound (Y) Compound (Z)

26 Element (X) / As it requires to be excited to absorb an amount of energy sufficient for the electron to transfer from the lower energy level (n = 2) to the higher energy level (n = 6).

27 (1) The bond length in the molecule of hydrogen chloride

= r (H) + r (Cl) = 0.3 + 0.99 = 1.29 Å

(2) The bond length in the formula unit of sodium chloride

= r (Na^+) + r (Cl^-) = 0.95 + 1.81 = 2.76 Å

Answers of exam model 4

Question number	1	2	3	4	5	6	7	8	9	10
Answer	c	d	c	d	a	a	c	d	c	b

Question number	11	12	13	14	15	16	17	18	19	20
Answer	a	c	b	a	d	c	b	a	d	a

Question number	21
Answer	b

22 The electronic configuration : $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^1$

Atomic number = 13

23 The electronic configuration of the element : [Ne] , $3s^2 , 3p^4$

∴ The element is located in the third period, group 6A (16).

24 [Ar] , $4s^2 , 3d^{10} , 4p^3$

25 (1) Zero.

(2) Zinc (Zn) and sulphur (S) combine together to form zinc sulphide.

26 Atomic radius of hydrogen $= \dfrac{\text{Bond length in hydrogen molecule}}{2}$

$r\,(H) = \dfrac{0.6}{2} = 0.3\ \text{Å}$

Atomic radius of nitrogen =

Bond length in NH_3 molecule – Atomic radius of hydrogen

$r\,(N) = 1 - 0.3 = 0.7\ \text{Å}$

Atomic radius of oxygen =

Bond length in H_2O molecule – Atomic radius of hydrogen

$r(O) = 0.96 - 0.3 = 0.66$ Å

Bond length in NO molecule =

Atomic radius of nitrogen + Atomic radius of oxygen

$r(N) + r(O) = 0.7 + 0.66 = 1.36$ Å

27 (1) The atomic numbers of these elements.

(2) All of them are metalloids.

Answers of exam model 5

Question number	1	2	3	4	5	6	7	8	9	10
Answer	c	b	b	d	a	c	b	d	d	b

Question number	11	12	13	14	15	16	17	18	19	20
Answer	a	b	c	c	a	d	d	d	d	b

Question number	21
Answer	b

22 **Bromine :** – 324.5

Iodine : – 295

23 Each principal energy level consists of a number of energy sublevels equals its number (n value = Number of ℓ values).

24 (1) Dalton's theory.

(2) Compounds are formed by the combination of atoms of different elements in a simple numerical ratio.

25 $Rb_2O_{(s)} + H_2O_{(l)} \longrightarrow 2RbOH_{(aq)}$

26 **(1) The electronic configuration :** $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^1$

$\therefore$ The atomic number = 13

(2) Group number 3A (13).

27 $r\,(O) = \frac{1.32}{2} = 0.66$ Å

$r\,(H) = 0.96 - 0.66 = 0.3$ Å

$2r\,(H_2) = 2 \times 0.3 = 0.6$ Å

Answers of exam model 6

Question number	1	2	3	4	5	6	7	8	9	10
Answer	d	b	d	b	c	d	b	b	b	c

Question number	11	12	13	14	15	16	17	18	19	20
Answer	a	a	a	c	c	c	d	c	b	c

Question number	21
Answer	b

22 $n = 5$, $l = 1$, $m_l = 0$, $m_s = +\frac{1}{2}$

23 $n = 3$, $l = 0$, $m_l = 0$, $m_s = +\frac{1}{2}$

24 The orbital.

25 Because the values of the electron affinity of these elements are nearly zero, where the atom becomes more stable when the sublevels :

- *1s* , *2s* , *3s* are completely filled as in He , Be , Mg
- *2p* , *3p* are completely filled as in Ne , Ar
- *2p* is half filled as in N

And adding a new electron to any of these atoms decreases its stability.

26 (1) (B) and (C).

(2) The charge of the nucleus is similar to the charge of positive alpha particles, so it repels them on approaching to it.

27 (1) * SO_2 oxide.

* **Oxidation number :** $\overset{?}{S}\overset{-2}{O_2}$, $S + (-2 \times 2) = 0$, $\therefore S = +4$

(2) * Cl_2O oxide.

* **The equation :** $Cl_2O + H_2O \longrightarrow 2HClO$

Answers of exam model 7

Question number	1	2	3	4	5	6	7	8	9	10
Answer	c	a	c	b	c	d	d	c	b	c

Question number	11	12	13	14	15	16	17	18	19	20
Answer	c	c	c	c	d	c	b	b	d	d

Question number	21
Answer	b

22 Zero / As potassium is among the elements of group (1A), where the oxidation number of any metal in this group in its compounds = +1

23 2 electrons.

24 No / Because the ionization potential of phosphorus $_{15}P$ is higher than that of sulphur $_{16}S$ despite the fact that it precedes sulphur in the same period.

$_{15}P$: [Ne] , $3s^2$, $3p^3$

$_{16}S$: [Ne] , $3s^2$, $3p^4$

This is because the atom is more stable when $3p$ sublevel is half filled as in case of phosphorus, so removing an electron from this atom decreases its stability.

25 Q / s-block.

26 (1) (1) CO_2

(2) H_2O

(3) K_2CO_3

(2) **The oxygenated acid :** H_2CO_3

The hydroxy formula : $CO(OH)_2$

$n = 1$, $m = 2$

27 (1) (1) Cl – Cl

(2) I – I

(3) Br – Br

(4) F – F

(2) $r(H) + r(Cl) = 0.3 + 0.99 = 1.29$ Å

Answers of exam model 8

Question number	1	2	3	4	5	6	7	8	9	10
Answer	b	b	c	d	d	a	c	d	b	d

Question number	11	12	13	14	15	16	17	18	19	20
Answer	a	a	b	d	a	d	c	c	d	c

Question number	21
Answer	d

22 XCl_2

23 Sulphuric acid H_2SO_4 / As it is more active, where the number of oxygen atoms nonbinded with hydrogen in sulphuric acid $SO_2(OH)_2$ is higher than in $ClO(OH)_2$

24 Number of the representative elements in the first period = 1 element.
Number of the representative elements in the second period = 7 elements.
The difference between them = 7 – 1 = 6 elements.

25 (1) (1) $1s^1$ (2) $1s^2$, $2s^2$, $2p^3$

(2) Zero.

26

Quantum numbers	n	l	m_l	m_s
First electron	2	1	−1	$+\frac{1}{2}$
Second electron	2	1	−1	$-\frac{1}{2}$

(1) Dalton's theory.

(2) The element is composed of very minute particles called atoms.

Answers of exam model 9

Question number	1	2	3	4	5	6	7	8	9	10
Answer	d	c	a	d	c	a	a	b	c	c

Question number	11	12	13	14	15	16	17	18	19	20
Answer	b	c	c	c	d	a	a	c	c	b

Question number	21
Answer	a

22 ∵ The electronic configuration of the element ends with $3p^4$ sublevel.

∴ The element is located in the third period, group 6A (16).

23 X : $1s^2$, $2s^2$, $2p^6$, $3s^1$

Y : $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^4$

Z : $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $4s^2$

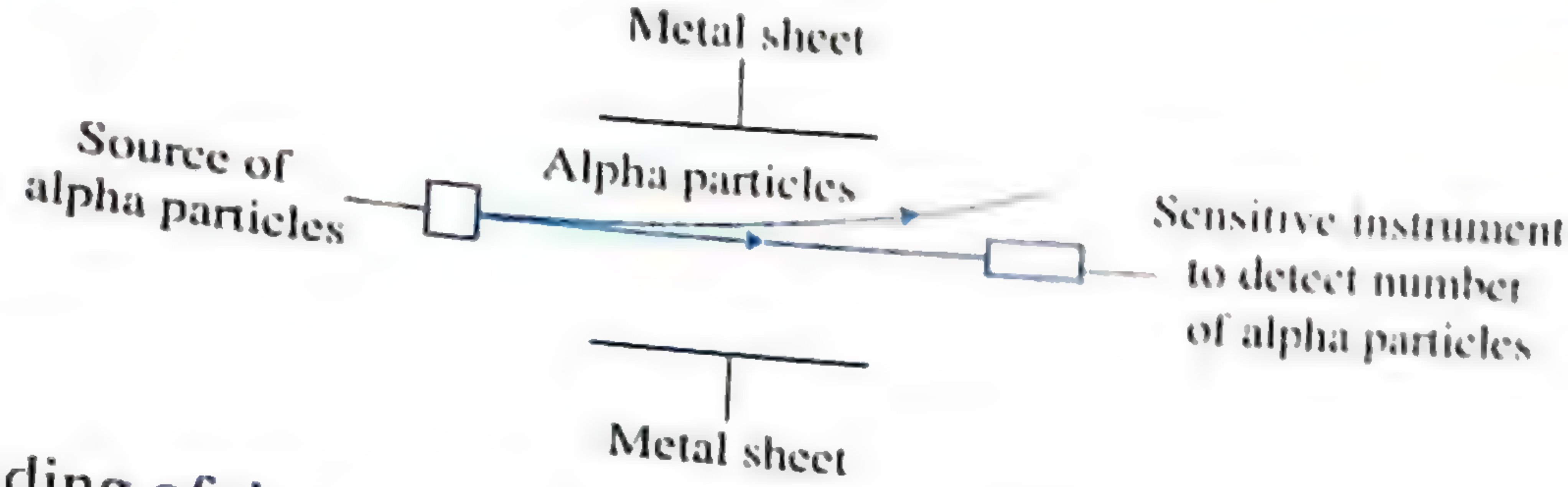
Element X / Because this results in breaking a completely filled energy level

24 **Sulphuric acid : $SO_2(OH)_2$**

Sulphurous acid : $SO(OH)_2$

∴ Sulphuric acid is more acidic / As the strength of the oxygenated acid increases by increasing the number of nonbinded oxygen atoms with hydrogen.

25 (1)



(2) The reading of the sensitive instrument decreases.

26 $r(H) = 1.29 - 0.99 = 0.3$ Å

$2r(H_2) = 2 \times 0.3 = 0.6$ Å

$r(N) = 1 - 0.3 = 0.7$ Å

$2r(N_2) = 2 \times 0.7 = 1.4$ Å

∴ Bond length in nitrogen molecule (N_2) is longer than that in hydrogen molecule (H_2).

27 **Cr :** $4s^1$, $3d^5$

Cu : $4s^1$, $3d^{10}$

Answers of exam model 10

Question number	1	2	3	4	5	6	7	8	9	10
Answer	c	c	a	a	d	d	b	a	d	d

Question number	11	12	13	14	15	16	17	18	19	20
Answer	c	d	d	d	a	c	d	b	c	b

Question number	21
Answer	b

22 d-block.

23 HO

24 Acid (3) > Acid (1) > Acid (2).

25

	First group	Second group
Elements	1, 2, 4, 5	3, 6
Type of elements	Representative elements	Noble elements

26 $\overset{0}{P} \xrightarrow{\text{Oxidation}} H_3\overset{+5}{P}O_4$, $H\overset{+1}{Cl}O \xrightarrow{\text{Reduction}} H\overset{-1}{Cl}$

Reducing agent : P , **Oxidizing agent :** HClO

27 **(1) The electronic configuration :** $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^3$

Number of completely filled orbitals = 1 + 1 + 3 + 1 + 3 + 1 + 5

= 15 orbitals.

(2) 3 electrons.

Answers of exam model 11

Question number	1	2	3	4	5	6	7	8	9	10
Answer	d	c	c	c	c	a	b	d	c	b

Question number	11	12	13	14	15	16	17	18	19	20
Answer	d	a	b	d	a	b	c	b	d	a

Question number	21
Answer	a

22. No / Due to the similarity of the two electrons of $1s$ sublevel in all four quantum numbers.

23. M : $1s^2$, $2s^2$, $2p^6$, $3s^1$

Because the second ionization potential of the element M is very high, where it causes breaking of a completely filled energy level.

24. $\overset{+5}{(ClO_3)^-} \xrightarrow{\text{Reduction}} \overset{-1}{Cl^-}$, $\overset{-1}{I^-} \xrightarrow{\text{Oxidation}} \overset{0}{I_2}$

Oxidizing agent : $(ClO_3)^-$ **Reducing agent :** I^-

25. Figure (2) / Bohr.

26. (1) • **The electronic configuration :** $1s^2$, $2s^2$, $2p^3$

• **The location :** Second period, group 5A (15).

(2) p-block.

27. (1) 29 elements.

(2) [Ar] , $4s^2$, $3d^{10}$, $4p^2$

Answers of exam model 12

Question number	1	2	3	4	5	6	7	8	9	10
Answer	d	c	d	c	d	d	c	d	a	c

Question number	11	12	13	14	15	16	17	18	19	20
Answer	b	a	d	a	d	a	b	c	b	c

Question number	21
Answer	c

22 Because *p* sublevel contains three orbitals, each orbital is filled with 2 electrons.

23 Co^{3+} : [Ar] , $4s^0, 3d^6$ $\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

∴ **Number of unpaired electrons :** 4 electrons.

24 Representative, main transition, inner transition and noble elements.

25 **(1)** Dalton's theory.

(2) Masses of the atoms of the same element are similar, but they differ from an element to another.

26 **(1)** First ionization potential.

(2) Used in detecting invisible alpha particles, where it flashes when these particles collide with it.

27 **(1)** ∵ **The hydroxy formula of the acid :** $PO(OH)_3$

∴ Number of nonbinded oxygen atoms with hydrogen in this acid = 1

(2) $3MgO + 2H_3PO_4 \longrightarrow Mg_3(PO_4)_2 + 3H_2O$

Answers of exam model 13

Question number	1	2	3	4	5	6	7	8	9	10
Answer	c	a	c	d	a	b	a	d	b	b

Question number	11	12	13	14	15	16	17	18	19	20
Answer	d	d	c	b	c	c	d	b	d	d

Question number	21
Answer	c

22 $r(Li^+) + r(Cl^-) = 0.68 + 1.81 = 2.49$ Å

23 Yes / As the cathode rays move in straight lines.

24 B, C and D / Because the excited electron transfers in the atom from higher energy level to lower energy level (its ground state).

25 (1) 3A (13)

(2) +6

26 (1) ∵ **Compound (Y) :** $ZnSO_4$

∴ The electronic configuration of the cation Zn^{2+} : [Ar] , $3d^{10}$

(2) Sodium zincate.

27 (1) **Case (1) :** $\ell = 0$, $m_\ell = 0$

Case (2) : $\ell = 1$, $m_\ell = 0$

(2) $n = 1$

Answers of exam model 14

Question number	1	2	3	4	5	6	7	8	9	10
Answer	b	a	a	c	d	d	a	a	c	b

Question number	11	12	13	14	15	16	17	18	19	20
Answer	c	c	d	b	d	a	a	b	a	c

Question number	21
Answer	c

22 d-block.

23 ∵ **Sublevels :** $5s$, $5p$, $5d$, $5f$

∴ Number of orbitals = 1 + 3 + 5 + 7 = 16 orbitals.

24 7.7% (H) : 92.3% (C)

As the proportions (ratios) of the components of the compound remain constant, no matter how different its mass, according to Dalton's postulate.

25 **(1)** Perbromic acid ($BrO_3(OH)$) is stronger than hypobromous acid ($BrOH$), as the strength of the acid increases by increasing the number of nonbinded oxygen atoms with hydrogen.

(2) $\overset{+1\ ?\ -2}{HBrO}$, $1 + Br - 2 = 0$ $\therefore Br = +1$

$\overset{+1\ ?\ -2}{HBrO_4}$, $1 + Br + (-2 \times 4) = 0$ $\therefore Br = +7$

26 **(1) The electronic configuration of the element (C) : [Ne] , $3s^2$, $3p^1$**

The quantum numbers of the last electron in the atom of the element (D)

$n = 3$, $l = 1$, $m_l = 0$, $m_s = +\frac{1}{2}$

(2) $E_2O_5 + 3H_2O \longrightarrow 2H_3EO_4$

27 (1) Because increasing the number of positive protons more than that of negative electrons results in increasing the nucleus effective charge leading to decreasing the size of the ion.

(2) Ca : $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2$

Number of orbitals = 1 + 1 + 3 + 1 + 3 + 1 = 10 orbitals.

Answers of exam model 15

Question number	1	2	3	4	5	6	7	8	9	10
Answer	d	c	a	b	d	a	c	a	c	d

Question number	11	12	13	14	15	16	17	18	19	20
Answer	a	d	c	d	b	a	b	d	b	b

Question number	21
Answer	b

22 **(1)** 7A (17) / Because the 8^{th} ionization potential of element (Y) is much higher than its 7^{th} ionization potential.

(2) (X) : $1s^2 , 2s^2 , 2p^6 , 3s^2 , 3p^4$

23 **(1)** Dalton's theory.

(2) Compounds are formed by the combination of atoms of different elements in simple numerical ratios.

24 **(1)** Yes.

(2) Alpha particles : Are deflected slightly towards the negative electrode.

Beta particles : Are deflected significantly towards the positive electrode.

25 **Symbol :** F

Block : p

26 $Se_{(g)} + e^- \longrightarrow Se^-_{(g)}$ + Energy , $\Delta H = (-)$

27 $_{29}Cu^+$ **:** [Ar] , $3d^{10}$

$_{30}Zn^{2+}$ **:** [Ar] , $3d^{10}$